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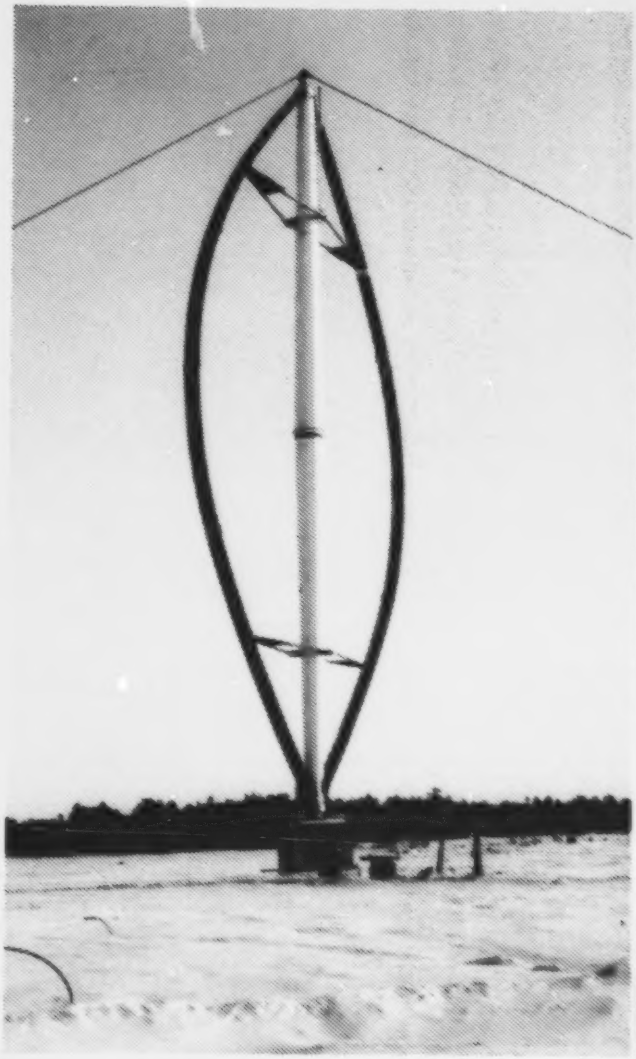
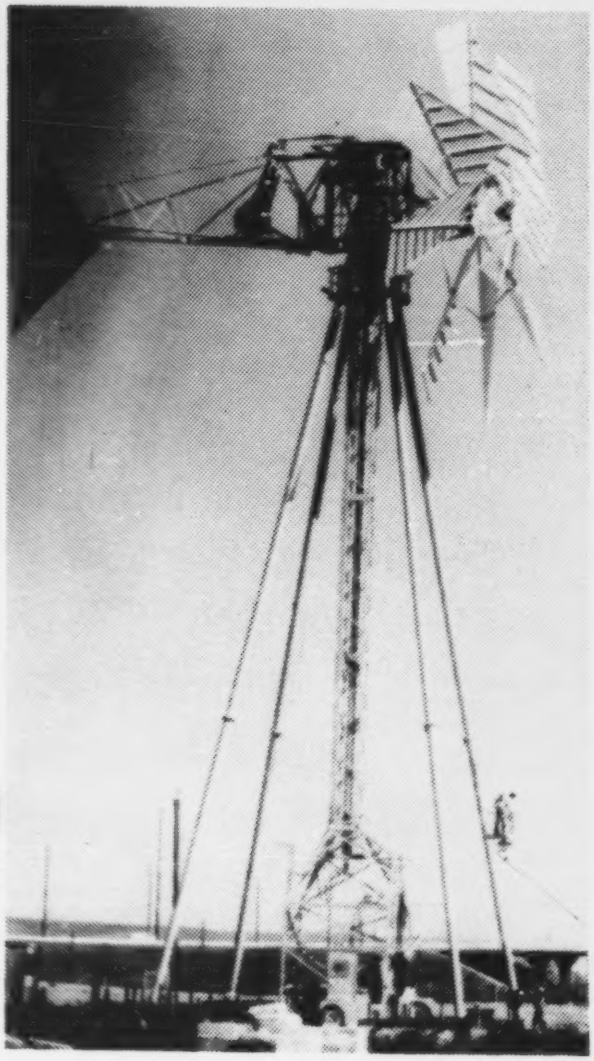
THE LEADING EDGE '84

The Seventh Annual **Wind Energy Symposium**

December 10th & 11th, 1984
Harbour Castle, Hilton, Toronto, Canada

PROCEEDINGS





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7TH ANNUAL WIND ENERGY SYMPOSIUM
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PROCEEDINGS
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DECEMBER 10th and 11th,1984

Harbour Castle Hilton
Toronto, Canada

EDITOR:

Nicholas J.M. Teekman, B.Sc.
DynamoGenesis Inc.

These proceedings are a record of the 'state of the art' in 1984 of Canada's research, test, development and planning methodologies and HAWT/VAWT industrial WECS technology. It is published as a public service for the information of the public.

SEVENTH ANNUAL WIND ENERGY SYMPOSIUM

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INTRODUCTION

If I could have your attention please, we will begin the symposium now. We are running 20 minutes late at this point so it is time to get going.

My name is Nicholas Teekman. I am the president of the DynamoGenesis Corporation and the symposium manager. On behalf of the DynamoGenesis Corporation, the Steering Committee and the sponsors of the Seventh Annual Wind Energy Symposium, I would like to welcome you here today to the Harbour Castle Hilton.

Since lunch is open this afternoon I'd suggest if you are so inclined to go up to the top of the hotel's tower and perhaps take in the revolving Lighthouse Restaurant. You might notice the Leslie Street spit which is off to the south-east which they are just in the process of developing now and I think in the future might turn out to be an ideal wind test site.

Regardless, it is my pleasure and honour to introduce to you the symposium chairman, Malcolm Lodge. Malcolm is a professional engineer. He is the wind programme manager with Resource Ventures Inc. in Prince Edward Island and he is a director of the Atlantic Wind Test Site. He has carried out wind energy research and development, and demonstration projects for seven years. So I give you Malcolm Lodge. Malcolm....

Malcolm Lodge

Thank you, Nicholas. Good morning, Ladies and Gentlemen. It's a pleasure to be selected as your chairman for this Wind Symposium, the Seventh Annual Wind Symposium that DynamoGenesis has organized in Canada. I hope that for the benefit of you here, that our numbers increase. We expect more people than this so we hope to have the room more filled out by the later part of the morning. You will notice on the blackboard to my left that there is a sign that says that the people who are not going to smoke can sit over on this side with those few people and this side was reserved for smokers.

In the package that you have been given are some papers that I thought I would take a moment to explain to you. You will notice in the programme that this afternoon we have scheduled the Charter Meeting of the Canadian Wind Energy Association. In the package are three pieces of paper that we would ask you to pay a little bit of attention to throughout the day.

One of those is a questionnaire which we have put together to give us a little information of what your feelings are with respect to the activities the fledgling organization should begin to deal with during its first days. The orange paper is a nomination form for the election of directors of the organization. On it you may nominate and obtain a seconder for someone who you may wish to have stand as a director of the Canadian Wind Energy Association. The election will be held at the Charter Meeting this afternoon. The other paper, a blue one, is the ballot that we will be using and also an opportunity at the bottom of that ballot for you to state whether you think our dues structure is reasonable and whether the aims and objectives and goals of the organization are appropriate. I would ask that if you do wish to nominate someone that you obtain their permission and an indication from them that they will allow their name to stand and will serve as a director if elected.

This evening at eight o'clock will be the symposium banquet. For those of you who have not yet purchased a ticket, we would request that you do so at the coffee break immediately following this session so that the symposium organizer may inform the hotel staff just how many people will be attending the banquet. It should be, in spite of our small numbers, a very good banquet. The banquet speaker will be Andrew Wells, who will give us the address for the evening, and I have been informed that he has some very topical and interesting things to say.

THE WAKE

STATUS AND OUTLOOK FOR
WIND ENERGY RESEARCH AND DEVELOPMENT IN CANADA CIRCA 1984

by

M.S. Chappell
Manager, Wind Energy R&D

National Research Council, Canada

Keynote address at

THE LEADING EDGE '84
Seventh Annual Wind Energy Symposium

DECEMBER 1984

Harbour Castle Hotel, Toronto

INTRODUCTION

Good morning ladies and gentlemen. I am pleased and honoured to have been asked to deliver the opening address at this 7th Annual Wind Energy Symposium. I have titled my paper "THE WAKE" for two reasons. First, in the aerodynamic sense a wake is what is left behind as the leading edge continues onward. In this sense I shall provide a brief overview of the current status of wind energy technology in Canada, together with my views of the technical outlook and the present research and development priorities. The second meaning of the word WAKE is that used by the Irish to describe a party held to honor the dead. As most of you already know, recent governmental directives require that the NRC Energy Division reduce all energy research and development activities conducted under the aegis of the interdepartmental Panel on Energy Research and Development (PERD) to zero within 24 months, after which time the Division will cease to exist. I will review the specific ramifications of these directives on the NRC Wind Energy R&D Program later in my presentation.

WIND ENERGY TECHNOLOGY

Wind Resource Characterization

Wind is a manifestation of solar energy resulting from differential heating of parts of the earth's atmosphere and the consequent movement of air masses from high to low density regions. To the height of even the largest earth-mounted wind energy conversion systems (WECS), the flow regime is within the atmospheric boundary layer. Thus local flow is affected by nearby topography and the velocity usually increases with height above the ground (FIGURE 1). Moreover, there are significant changes of wind velocity with time (FIGURE 2) ranging from seasonal variations, through daily fluctuations related to day/night patterns, to gusts of only a few minutes duration, and turbulence with time constants of the order of one second. The time history of windspeed is usally expressed in the form of a histogram of duration vs velocity (FIGURE 3). All of these idiosyncracies must be accounted for by the successful wind turbine designer. Many data have already been accumulated on wind as part of long term meteorological records throughout most populated parts of Canada. The Atmospheric Environment Service (AES) of Environment Canada has published Canadian Climate Normals (FIGURE 4) of which Volume 5 provides monthly values of wind speed and direction at about 400 locations. Data from this and other sources have now been reworked and a series of reports will be issued shortly providing detailed regional data on wind energy densities and other parameters particularly suitable for wind energy users (FIGURE 5).

These data represent the best utilization possible of the long term meteorological data. Nevertheless, detailed wind information is often required for a candidate site far from the nearest AES station. Two approaches may be considered in this situation. Instrumentation can be erected at the site (FIGURE 6) and about one year's data recorded and analysed to assess wind energy potential. NRC has provided approximately thirty wind histogram recorders to serious potential users of wind energy, to monitor winds at mutually agreed candidate sites. Monthly reports are distributed to all participants in this assessment activity. As an adjunct to this wind "prospecting" program NRC and AES are evaluating a dozen different makes and models of anemometers and readout devices. Accurancy, sensitivity, durability, and reliability are being assessed both in AES wind tunnels and at the Atlantic Wind Test Site.

An alternative to somewhat costly and time consuming site monitoring is to use analytic techniques whereby the wind regime at the candidate site can be interpolated from data recorded at nearby sites. This is often difficult to do with satisfactory accuracy in a country of the size and demographic distribution of Canada. AES, in conjunction with similar experts in other countries, have been working to develop analyses of flow over terrain using mathematical models, wind tunnel models, and full scale measurements in the field. The report of a major international field measurement exercise, led by Canada and involving six other countries, will be released by the International Energy Agency early next year.

Aerodynamic Performance Prediction

To predict the performance of a windmill rotor, standard aerodynamic relations are applied to each blade segment and the resulting lift and drag forces are then integrated over the entire blade to give power output and structural loads. To account for variations of velocity with height, this process must be repeated at a number of blade positions as a horizontal axis rotor spins in the non-uniform flow field. For vertical axis rotors the effect of the upstream blade on its downstream partners must be accounted for by considering the momentum decrease in the flow resulting from energy extraction by the upstream blade. Though complex, the methods are now highly developed and accurate. Typical performance curves (FIGURE 7) can be predicted to within 5%, providing adequate information exists on the airfoil shapes chosen. It should be noted that windmills require considerably more extensive airfoil information than needed for aircraft. For example, under certain operating conditions, the angle of attack on a VAWT blade may go completely around the airfoil, whereas $\pm 30^{0}$ is adequate for most aircraft design purposes. Moreover, in stall-controlled machines such as the Darrieus VAWT, the rapidly changing angle of attack significantly affects the stall characteristics of the airfoil (FIGURE 8). Failure to account for these effects can result in underprediction of power output and consequent overloading of drivetrain and electrical components.

Energy Yield Prediction Methods

Energy output per year can be computed by piecewise integration of the WECS power curve and the windspeed-duration curve that describes the site wind regime. This process is illustrated in FIGURE 9. From the site wind regime curve it is determined that the wind velocity is "V" for a total of "T" hours per year. From the WECS performance curve it is determined that at wind velocity "V" the WECS produces "P" kilowatts of power. Thus the energy produced during the whole year at wind velocity "V" is "PxT" kWh. Repeating this calculation for all wind velocities between CUT-IN and CUT-OUT and summing the energy values gives the total annual energy output for that WECS in that wind regime, assuming the machine is available to operate at all times (i.e. no down time). This, and other similar methods have been programmed on personal size micro-computers and reported in the open literature.

In addition to rotor performance and drivetrain efficiency, the total system engineering, including the controls, must be suited to the intended application. For example FIGURE 10 shows the relative energy yield of WECS with various power loadings as a function of site average windspeed. It is seen that differences of ±30% in energy output can occur between carefully or poorly chosen power loadings.

The WECS control system can have significant influence on system energy output. For example, the time taken to confirm sustained windspeed in the operating range has a much greater effect on energy yield at the cut-out end of the operating range than at the cut-in end. Indeed, the cut-out velocity setting itself significantly influences energy yield.

Structural Considerations

Darrieus wind turbines appear to be simple structural devices. Although the troposkien blade shape results in predominately tensile loads in the blades, elastic interactions with the guywires, the column, and the drivetrain produce a variety of complicated vibration modes at a series of frequencies (FIGURE 11). Sophisticated structural dynamic analysis techniques have now been developed by researchers in Canada, USA, Germany and Sweden. Though requiring large mainframe computers, these methods can predict mode shapes and frequencies as functions of rotor speed and the consequent structural changes induced by centrifugal force. The designer can then use the resulting "fan plot" (FIGURE 12) to ensure both steady-state and transient operating speeds do not encroach any dangerous frequencies. Similar programs exist to analyse the structural dynamic behaviour of HAWTS.

The selection of materials for windmills must reflect the often-arduous environments in which they must operate. Typically in Canada, wind turbine sites are exposed to dust, salt spray, rain, snow, icing, wide extremes of temperature, and high intensity sunlight. Aluminium and galvanized steel have performed well on prototype units, however, alternate base materials (fiberglass, wood etc.) and coatings (epoxy paint, oxide cladding, etc.) may offer economic, structural, or fabrication advantages.

WECS Development

The previous sections discussed some of the basic tools available to the wind turbine designer. Let us now look briefly at some prototype products produced with these tools. Because of the diffuse nature of the wind energy resource (750 W/m^2 is typical for a reasonably good site) wind turbines of significant power are physically large. In addition to cost effectiveness ramifications, this means testing of full scale hardware must be done outdoors. Thus many of the problems and failures that are inevitable in a developing technology occur in publicly visible areas. Unlike the gas turbine developer who has his disasters in the relative privacy of his test cell, the wind turbine developer suffers his miseries in public, with the consequent abundance of after-the-fact advice from all and sundry.

Partially for these reasons, but mainly to provide a well equipped, experienced test facility for use by WECS manufacturers and WECS users, the Atlantic Wind Test Site (AWTS) was established at North Cape, Prince Edward Island in 1981 (FIGURE 13). During its relatively short history, AWTS has tested and reported on some dozen windmills, spearheaded the development of Canadian WECS Testing Standards, and has established strong technical liasons with similar WECS test establishments in the USA and in Europe.

A series of small experimental VAWTS ranging from 1 to 5 kW rating were designed and built in 1979 by Bristol Aerospace with support from NRC (FIGURE 14). These units incorporated direct-drive permanent-magnet alternators and rectifiers to charge batteries powering telecommunications stations. Six units were deployed and operated sporadically for several years.

The first intermediate size prototype WECS built in Canada was the 230 kW VAWT designed and built by DAF Indal and installed on Iles de la Madeleine (FIGURE 15). Its extensive instrumentation provided much of the experimental data used to verify the aerodynamic and structural analysis tools referred to above. Today, its research purposes fulfilled, "Maggie" continues to contribute energy to the diesel-electric network on Iles de la Madeleine.

To provide operational data under typical conditions, and to provide potential users with hands-on experience with the new technology, a series of 50 kW grid-coupled WECS were installed during

1978-1982 in conjunction with various utility agencies throughout Canada. Four units continue to operate at Christopher Point, B.C.; (FIGURE 16) Swift Current, Saskatchewan (FIGURE 17); Churchill, Manitoba (FIGURE 18); and Holyrood, Newfoundland (FIGURE 19). An earlier model was removed from the Holyrood site after about 4500 hours operation, rigorously inspected at NRC, and found to be structurally sound. Cumulatively, these five units have logged 38000 hours of operation (31000 hours generating) and have contributed a total of over 370 MWh to their host utilities (FIGURE 20). Individual units are approaching 10,000 hr operation and availability is generally above 90%. Another similar unit is incorporated into a 50/100 kW wind/diesel autonomous powerplant to investigate system characteristics for remote community applications.

Based on the field trial experience described above, DAF Indal have designed and manufactured a 500 kW VAWT (FIGURE 21) which incorporates a rotor very similar to that used on the Iles de la Madeleine machine, and a number of innovative drivetrain concepts developed through the 50 kW series. The rotor comprises two 0.74 m chord, NACA 0015, airfoils made from single aluminum extrusions. Diameter and height are 24.4 m and 36.6 m respectively, giving a swept area of 595 m^2 and a power loading of 877 W/m^2. Twin 261 kW induction generators are driven by separate pinions meshing with the 2.5 m diameter bullgear. The first of these units is operated by the Southern California Edison company near Palm Springs in California. An extensively instrumented second unit was erected at AWTS in November 1983 and first rotation was made on 17 January 1984. Commissioning and instrumentation checkout were completed by late March. Less than 600 hours operation were accumulated during 1984 because of problems with drivetrain mechanical components, hydraulic oil leakage, and control system malfunctions. It is hoped that these problems have now been resolved and that the extensive structural and performance testing can be carried out without further interruptions.

Under another NRC contract ADECON Energy Systems Inc. have designed and manufactured a prototype 125 kW VAWT that incorporates an external lattice framework, rather than guywires, to support the upper end of the rotor (FIGURE 22). Rotor dimensions of the AES 125 are 17.0 m diameter by 25.5 m height giving a swept area of 283 m^2 and a power loading of 442 W/m2. The two blades are constant 0.6 m chord NACA 0018 airfoils comprising multiple thin-walled aluminum extrusions. The gearbox and induction generator are supported on lower framework members such that the blade equator is 25.5 m above ground. The major advantages claimed for the design are low cost, ease of transportation/installation, and appropriateness to moderate wind regimes. The prototype unit is being installed at AWTS in December 1984 for rigourous performance and structural evaluations.

DELTX Windpump Ltd. of Calgary have built a prototype large-scale water pumping windmill, based on the Kentfield delta-blade concept (FIGURE 23). The 16 m diameter, eight-bladed, horizontal axis WECS with integral twin cylinder reciprocating low-head high-volume pumps is intended for irrigation and pumped-hydro storage applications. The prototype has a predicted flow capacity of approximately 100 m^3/min with a 10 m lift in a wind speed of about 16 m/s at the hub height of 31.4 m. The unit has completed a 300 hour shakedown run and is currently undergoing quantitative performance tests.

Projet ÉOLE is a joint venture by Hydro-Québec and NRC to design, build and evaluate a 4 MW Darrieus VAWT (FIGURE 24). The 96 m x 64 m 2-bladed rotor will be built of steel. It will drive a rotor-speed generator at about 14 rpm, with an AC-DC-AC link to achieve frequency, phase angle, and voltage conformity to the grid. Work at the site near Cap Chat, Quebec, is well underway (FIGURE 25) and the external concrete work should be complete by Christmas. Assembly and erection will take most of next year and first rotation is scheduled for early 1986. Major component fabricators include

Versatile Vickers Inc., Canadian General Electric, and Hayes-Dana Corporation.

Technical strength for the design of these prototype systems is founded in the experience and knowledge of staff within NRC, augmented by several major technology studies performed under contract to NRC by WECS manufacturers and engineering consultants. These studies explore the sensitivity of technical and economic value to variations in many system design paramaters. All have been made publically available through technical libraries such as CISTI.

In addition to the NRC-supported projects mentioned above, several Canadian firms are designing and manufacturing horizontal and/or vertical axis wind turbines. Wellington Windpower, Thermax, and Extrawatt are but three such producers. Other knowledgeable companies provide applications engineering and servicing for various foreign brands of WECS. Howdens of Scotland have produced 300 kW and 60 kW units for the Orkneys, and are contemplating Canadian manufacture at the factory in Scarborough. All told, about a dozen experienced manufacturers and perhaps 30 engineering agencies comprise the current Canadian wind energy industry.

PERSPECTIVES

In 1973 Canadians were rudely made aware of the finite nature of petroleum reserves, and of the consequences of politically motivated disruptions in foreign supplies. During the intervening decade the short-term concerns have relaxed considerably. Conservation, the best of all energy sources, has stretched our reserves. Research, development, and industrial initiative have established appropriate applications for alternate energy sources such as bioenergy, solar energy, and wind energy. Not surprisingly, none has proved to be a panacea, and all have presented more significant technical and economic challenges than first anticipated.

Nevertheless, the long term need for new energy sources, especially on a global scale, has not dimished one iota. World Energy Conference predictions forcast a two-fold increase in population, with a concomittent three-fold increase in energy requirements by 2020.

In 1984 the prospects for domestic deployment of Canadian wind energy technology are somewhat different than those perceived in 1974. Committed construction of conventional generating plants, based on decade-old consumption escalation forcasts, has "overpowered" most Canadian utilities. This situation will likely persist for another decade until more gradual demand growth catches up. Hence, massive installations of megawatt-scale WECS to contribute to regional electrical supplies are unlikely before 1995, unless primarily export situations exceed current local generating capacities. This reprieve provides additional opportunity for researchers and industrialists to ensure the maturity and economic viability of the technology prior to its deployment.

In 1984 the Canadian domestic wind energy market is clearly in the remote areas. Over 800 diesel-generators, with a total rating of over 160 MW, are operating at this moment. Fuel costs for electricty from these systems range from about 8¢/kWh to about 75¢/kWh and in some instances exceed $1.00/kWh. Many of these sites have moderate to good wind regimes.

Experimental work at Sudbury has proven the technical viability of Canadian wind-diesel powerplants. In moderate wind regimes a well-engineered wind-diesel system can achieve 30% to 40% fuel savings. Retrofitting wind turbines into existing small diesel networks requires careful system engineering and control design. A comprehensive dynamic computer model is being developed by GasTOPS Ltd. on NRC's hybrid analogue/digital computer facility. This model will simulate the dynamic behaviour of any wind-diesel system described from a repetoire of components such as windmills, diesels, generators, storage devices, etc., and ultimately could permit interconnection of actual control system hardware for development or check-out. Simpler programs are being created at NRC and in industry to provide overall system performance and economic data.

If Canadian WECS are to establish technical and economic credibility in remote areas, considerable attention must be paid to detailed systems engineering for these applications. Reliability is of paramount importance, together with responsive and competent service. A one-month wait for diagnosis and replacement of a 13¢ resistor in the control sytem may equate to loss of 20% of the annual energy yield, not to mention loss of confidence by the user/owner. Transportation and erection procedures need special thought for remote applications. High capacity cranes are often not available in isolated communities and may not be technically feasible at certain hilly sites. Load variations in small networks are usually more severe. Failure to account for these distorted demand curves can lead to poor system economics or, in severe cases, to powerplant instabilities and consequent problems with both the windmill and the diesel-generators.

Confidence that prototype systems will operate satisfactorily in the harsh climates of most isolated Canadian communities must come from rigorous testing. Fortunately, experience and equipment is available at AWTS to undertake such work. Hopefully, financial and schedule allowances will be made for these essential evaluations within near-term demonstration projects.

Not all near-term domestic markets for Canadian WECS are isolated, single-unit installations. Two or three special opportunities exist for multi-unit arrays of intermediate-scale WECS. Iles de la Madeleine, with over 50 MW of diesel-generators and an annual average wind speed of nearly 10 m/s has to be an ideal wind energy site. Similar opportunities exist on the Queen Charlotte

Islands in B.C., and on Prince Edward Island.

The economic attractiveness of WECS in diesel-generator micro-networks depends on energy yield, installed cost, and maintenance costs. Early project estimates have shown that transportation, erection, connection, and ancilliary costs (such as site access, fencing, utility supervision, etc.) form a substantial fraction of the installed cost, together of course with the capital cost of the WECS machinery. Long term maintenance cost is generally unknown, and often the "worst case" is presumed which significantly reduces revenue flow. Subsidies for early demonstration projects could help to bridge the financial gap for non-mass-produced hardware. However, there are dangers that subsidies support immature technology and that subsidies reduce incentive to optimize cost effectiveness. Serious consideration should be given to supporting actual performance (i.e. subsidize energy yield) and to "ramped" subsidies with predetermined reductions over, say a five year period. The proliferation of misery in early Californian wind farms is the legacy of "too much, too soon". A still-born industry may be the legacy of "too little, too late".

The NRC Situation

Recent Canadian activity in wind energy R&D was initiated in 1966 by two engineers in NRC's Low Speed Aerodynamics Laboratory. Raj Rangi and Peter South were searching for a simple device to provide energy for pumping water and for generating small quantities of electricity in developing countries. These efforts were escalated and refocussed in 1975 to address the heightened Canadian interest in alternative sources for significant contributions to domestic energy supplies.

The escalation of the Canadian Wind Energy R&D (WERD) program during the decade 1974/1984 was characterized by increasing use of contracted-out projects in embryonic Canadian wind turbine industries. In 1974/75 the federal expenditure on wind energy R&D was $60 K, the majority of which was spent within NRC. In 1984/85 the federal wind energy R&D budget was $8.3 M, of which more than 90% was allocated to research contracts with private firms and provincial agencies, including about $5 M for Projet ÉOLE. All activities were co-ordinated under the aegis of the federal interdepartmental Panel on Energy R&D (PERD).

In November 1984 the Canadian Government decided, as part of a broad program of government spending reductions, that NRC would no longer participate in the energy activities under PERD. Both the budget and the staff of the NRC WERD program are virtually eliminated. Remaining resources are barely sufficient to honour existing contractural commitments. During the wind-down period the efforts of NRC staff will be focussed on interpreting, summarizing, and documenting the state of the technology we have developed. We are convinced this technology will be needed, both within Canada and as part of Canada's obligation and opportunity to help others in our world.

In the past decade Canada has become a credible technical participant in all areas of wind energy technology, including atmospheric flow, site assessment methods, aerodynamic and structural research and development, formation of standards, engineering and manufacturing of reliable efficient wind energy conversion systems.

NRC has spearheaded Canada's participation in the wind energy research agreements of the International Energy Agency and is currently Chairman of the Executive Committee of the Large Scale WECS R&D Agreement. Canada is the acknowledged world leader in vertical axis wind turbine technology and has provided data, analyses, and advice upon which US, German, and UK VAWT R&D programs were founded. These Canadian achievements will not be lost, and NRC is proud of its role through this dynamic period.

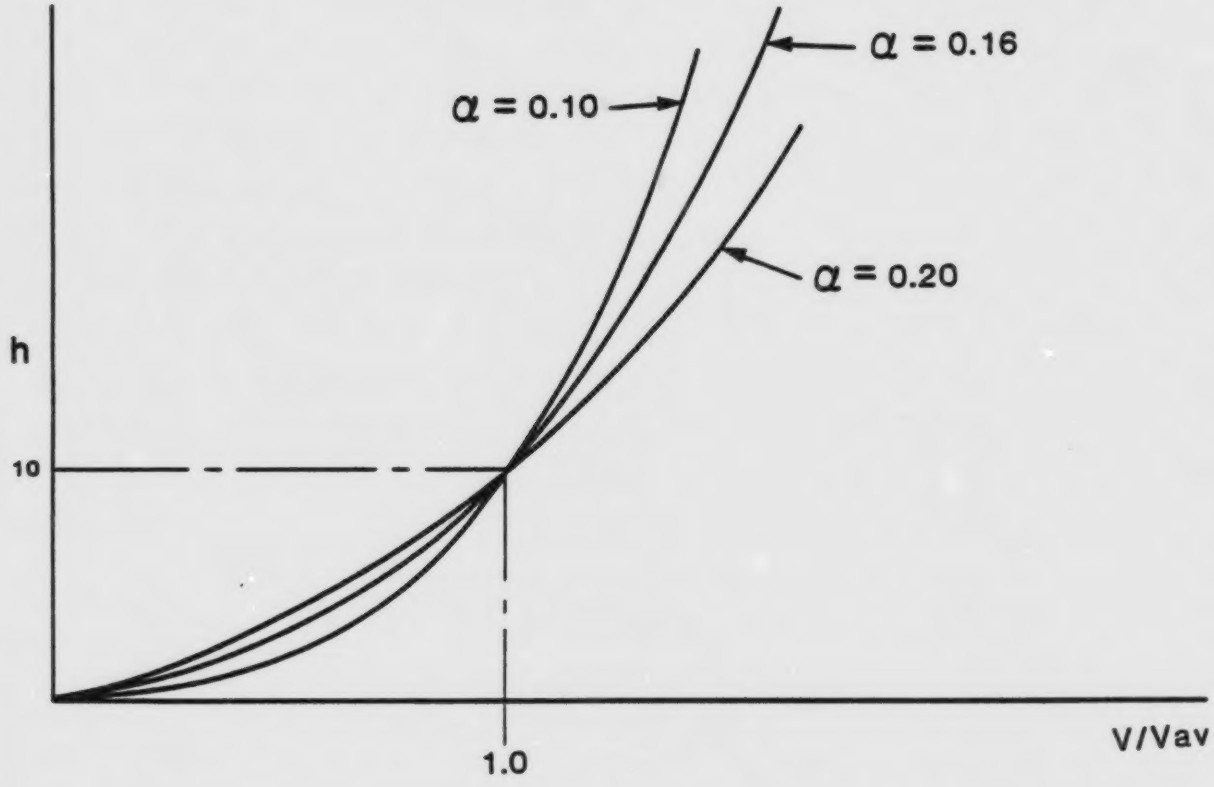
Future Activities

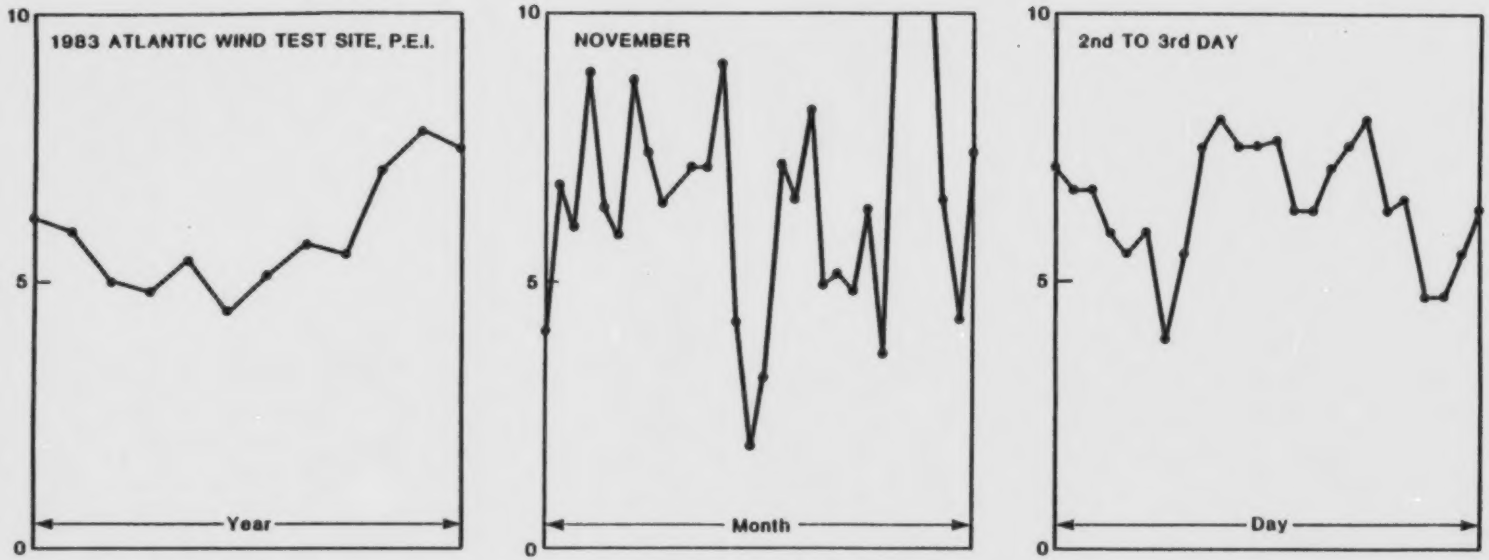
Though NRC's lead role in contracting-out wind energy R&D must now revert to a relatively small in-house activity of basic research in the Low Speed Aerodynamics Laboratory, there are other resources through which wind energy technology can continue to develop. As reviewed above, there are significant Canadian WECS systems at or very near the maturity required for sucessful demonstration. Energy, Mines and Resources (EMR) Canada has programs to support and monitor such projects. Manufacture of wind turbine systems in Canada is a viable industrial enterprise. The Department of Regional Industrial Expansion (DRIE) has programs to support industrial initiatives. Indeed, NRC's Industrial Development Office can potentially offer support through its PILP and IRAP programs. Representatives from all these agencies are here today or can be reached through my office. Finally, there is the Canadian Wind Energy Association, to be formed at this symposium later today. Now, perhaps to a greater extent than originally percieved, CANWEA must serve as a focal point for the technical and infrastructural matters which concern the entire wind energy community.

In closing, I offer a third, hopefully appropriate, connotation for my title. To WAKE is to begin, refreshed, with new perspective. I hope that it is this meaning that will be remembered as the keynote to THE LEADING EDGE - 84.

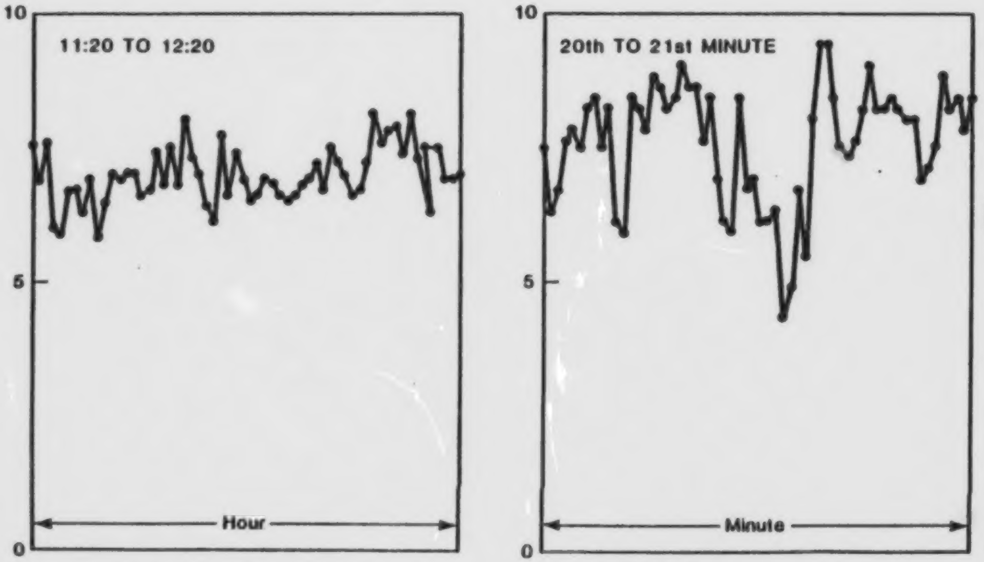
Thank you

Fig. 1. Wind Velocity Variation with Height





Monthly Average Daily Average Hourly Average



Minutely Average Secondly Average

Fig. 2 Wind Speed Averages
Over Different Time Periods

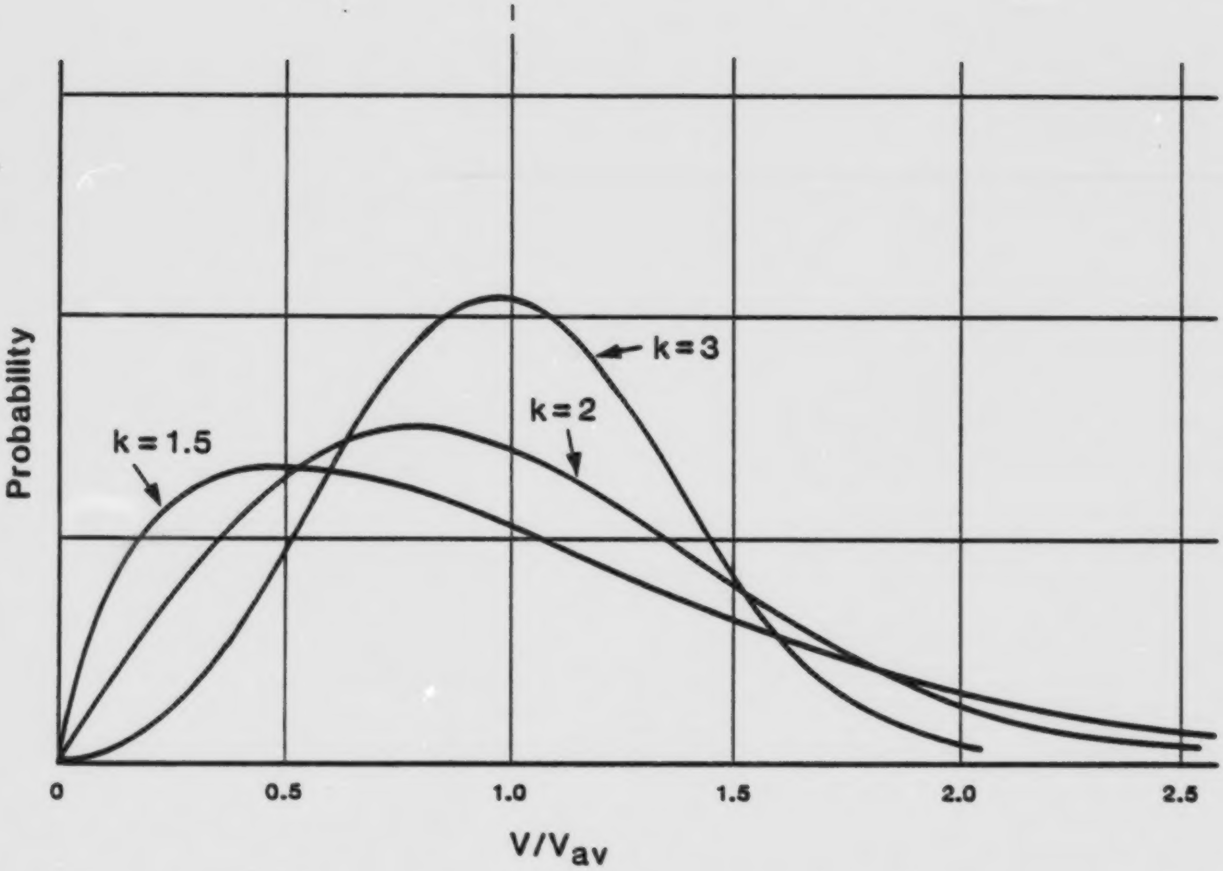
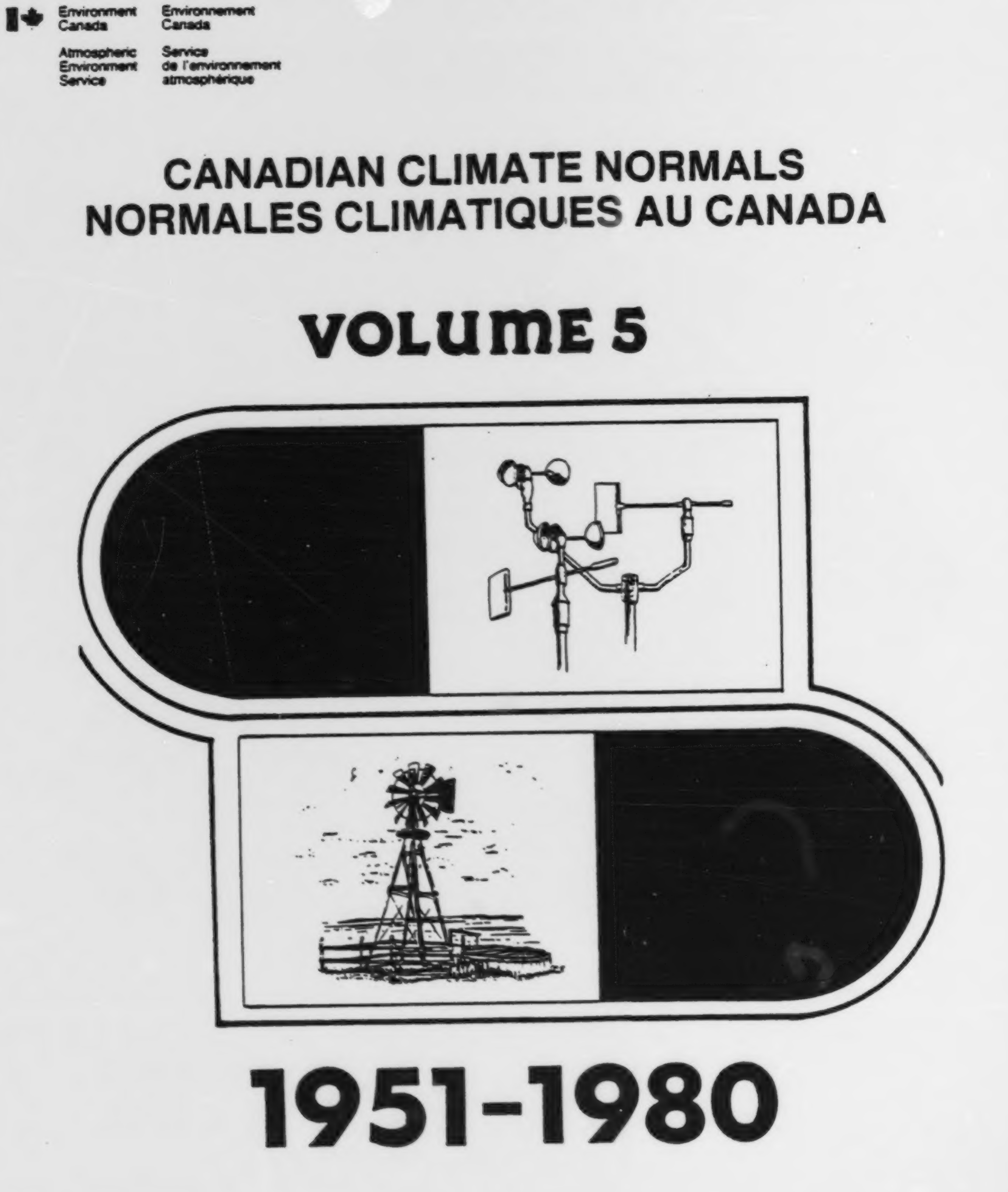


Fig. 3. Temporal Distribution of Wind Velocity



Environment Canada Environnement Canada

Atmospheric Environment Service
Service de l'environnement atmosphérique

CANADIAN CLIMATE NORMALS
NORMALES CLIMATIQUES AU CANADA

VOLUME 5

1951-1980

Canada

Fig. 4. Canadian Climate Normals - Volume 5 - Wind

WIND ENERGY DATA ANALYSES
FOR CANADA 1967-1976

Volume 3: Ontario

ANALYSE DES DONNÉES SUR
L'ÉNERGIE ÉOLIENNE POUR
LE CANADA 1967-1976

Volume 3: Ontario

Fig. 5 Wind Energy Data Analyses For Canada 1967/1976

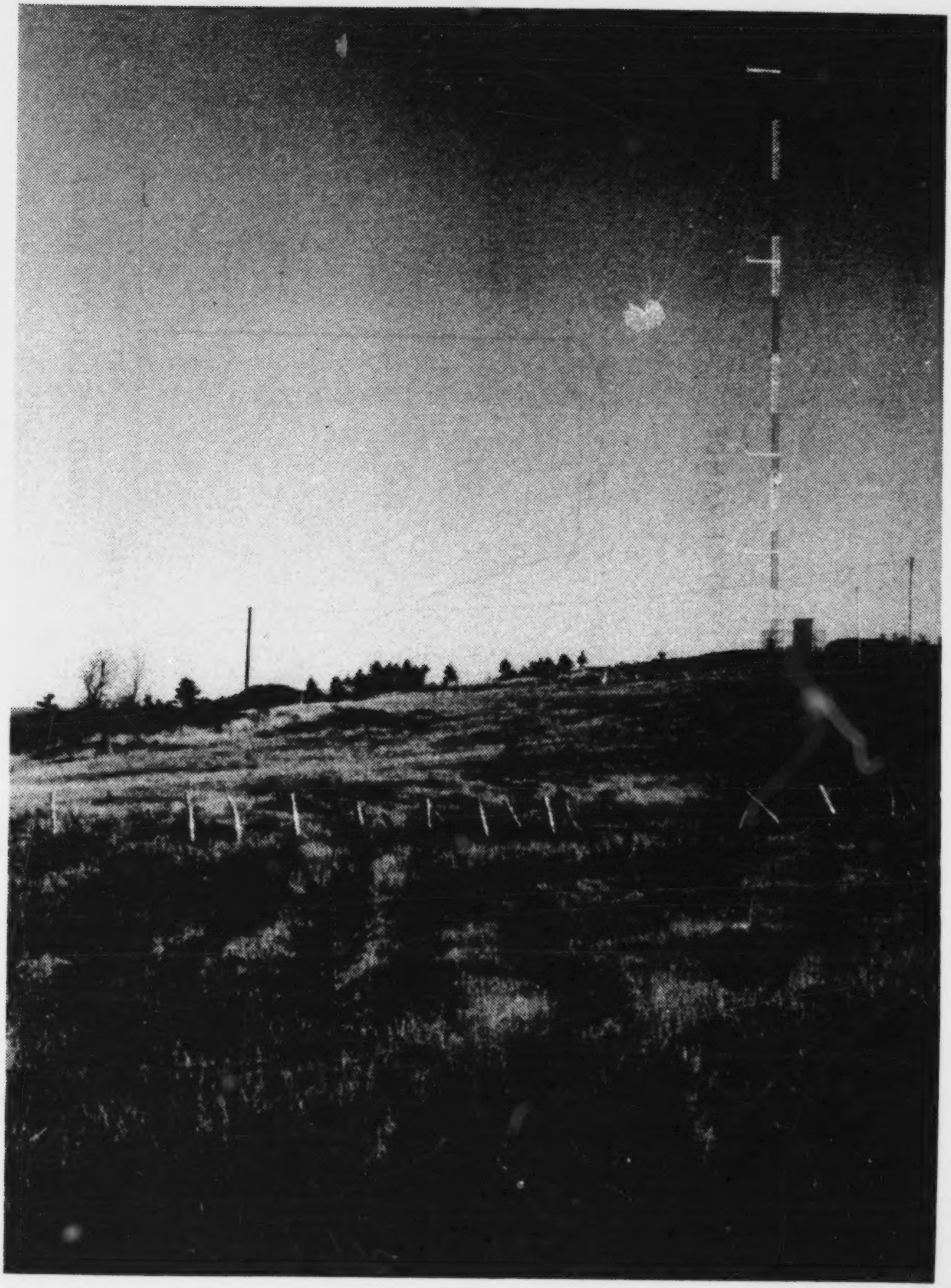
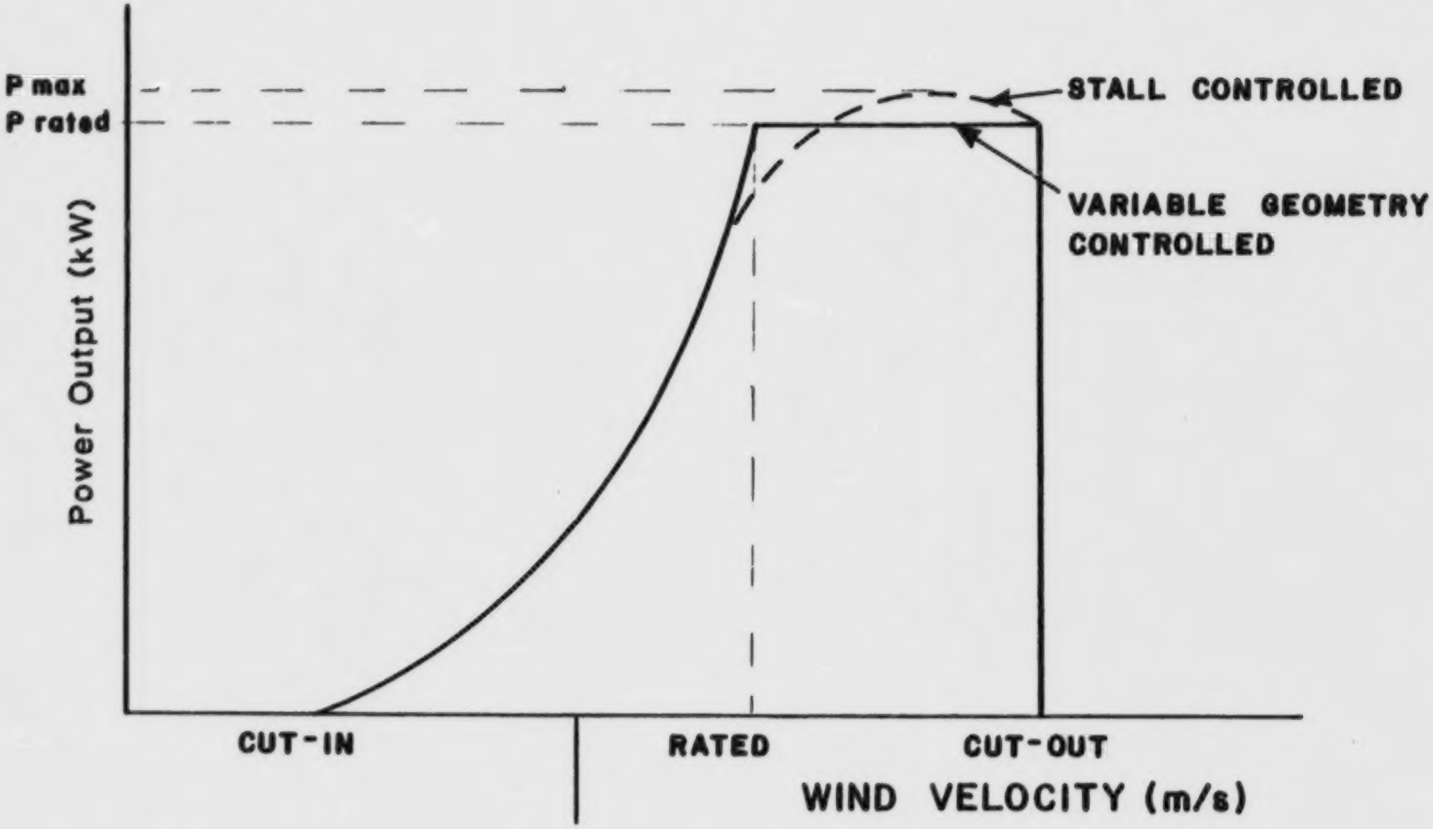


Fig. 6 Instrumentation For Site Evaluation

Fig. 7 TYPICAL WECS PERFORMANCE



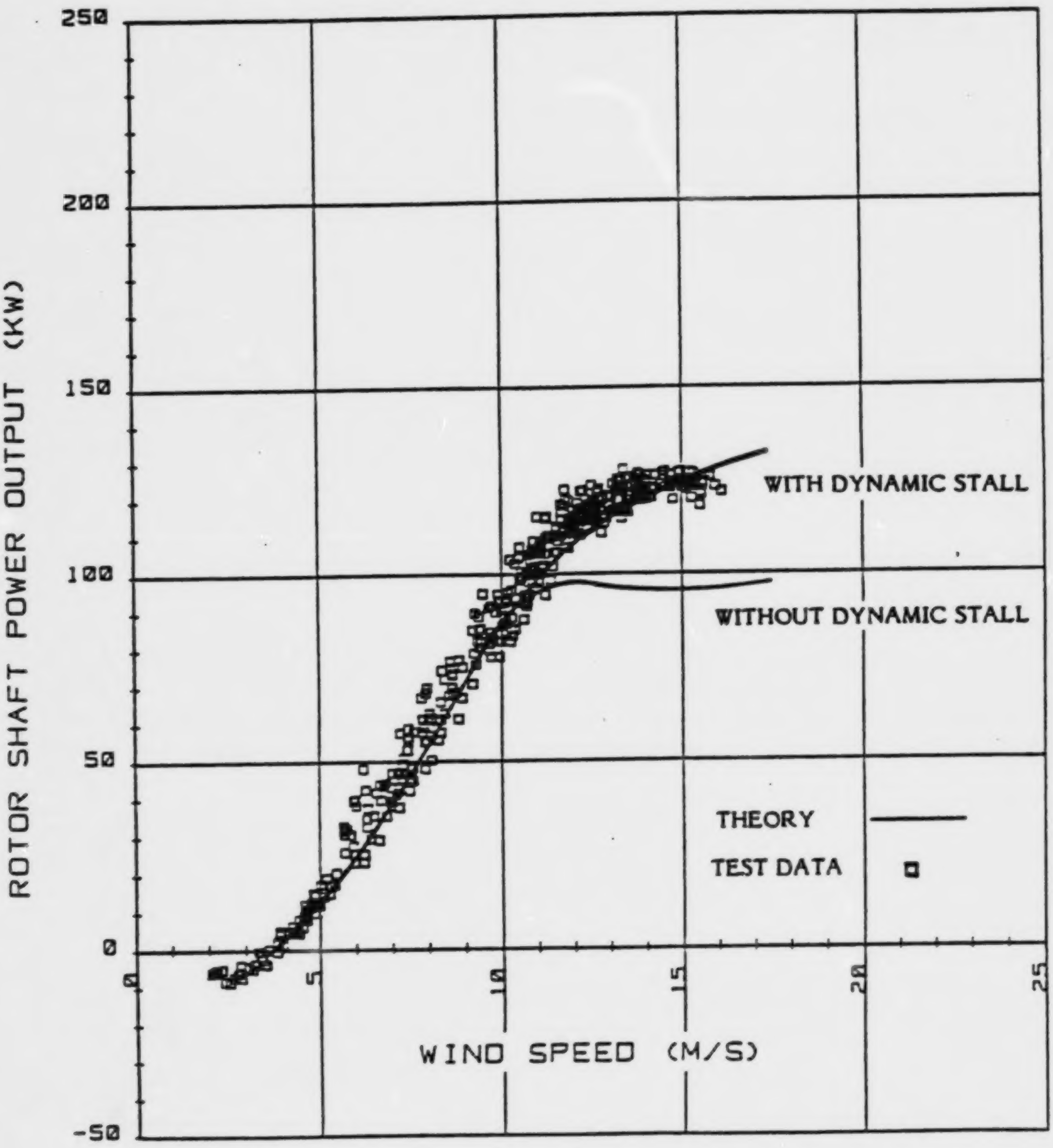


Fig. 8. Shaft Power VS Wind Speed – Magdalen Islands VAWT

(showing effects of dynamic stall)

Fig.9. Energy Calculation By Integration Of WECS Performance And Site Wind Regime Data

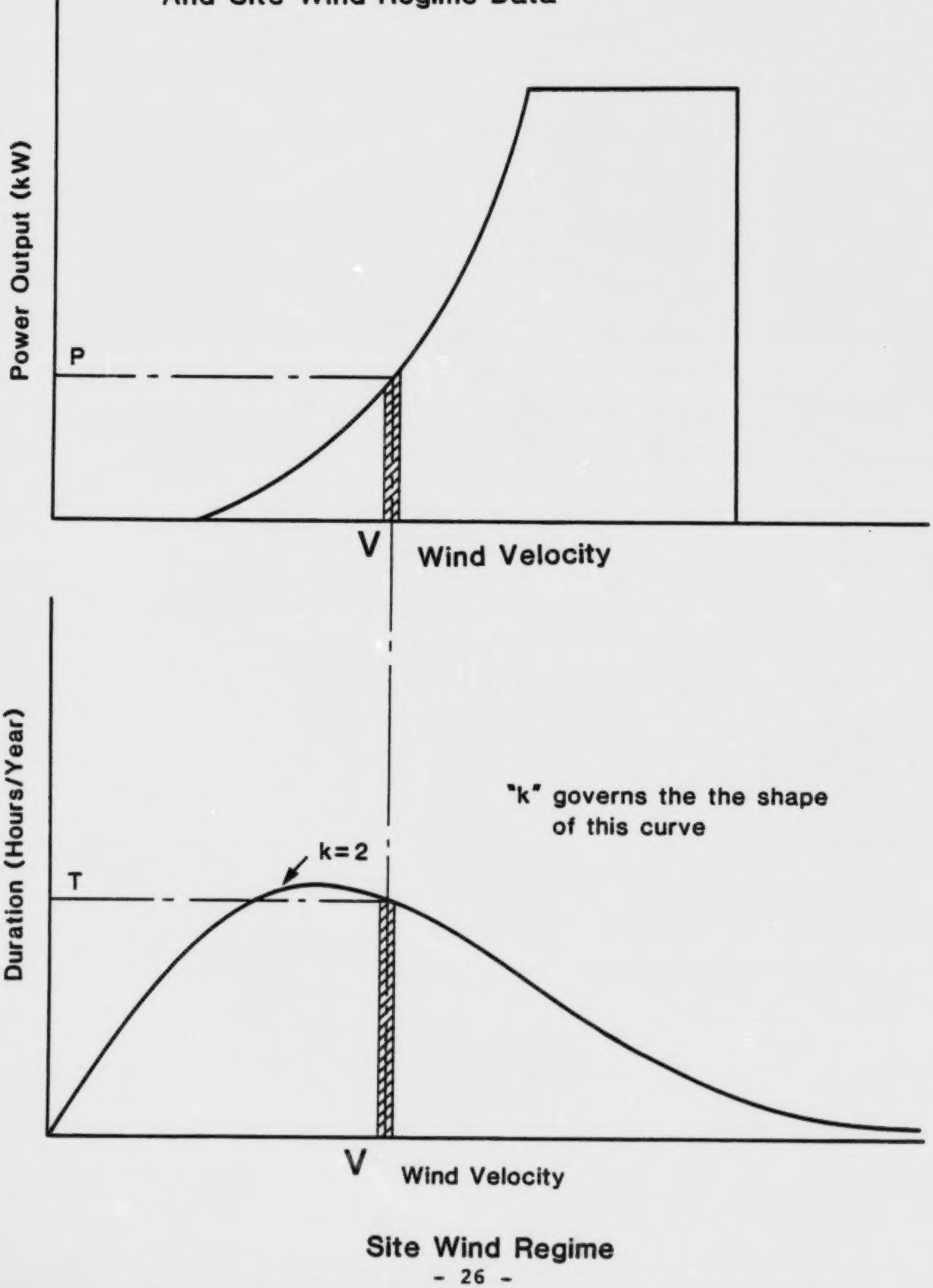
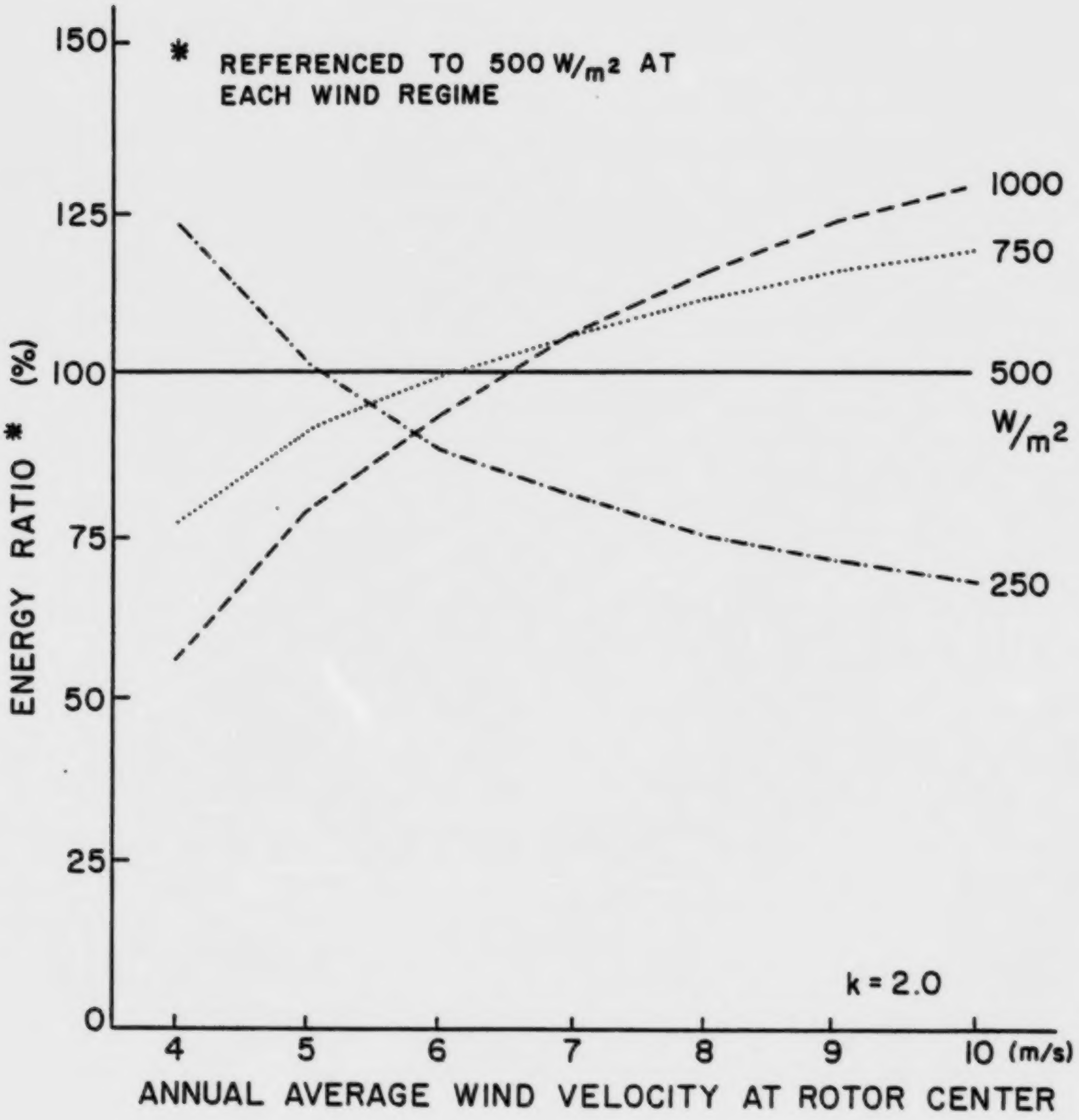

Power Output (kW)
P
V
Wind Velocity
Duration (Hours/Year)
T
k=2
"k" governs the the shape of this curve
V
Wind Velocity
Site Wind Regime

Fig. 10



RELATIVE ENERGY OUTPUT OF WELL DESIGNED WECS
(showing significance of Power Loading)

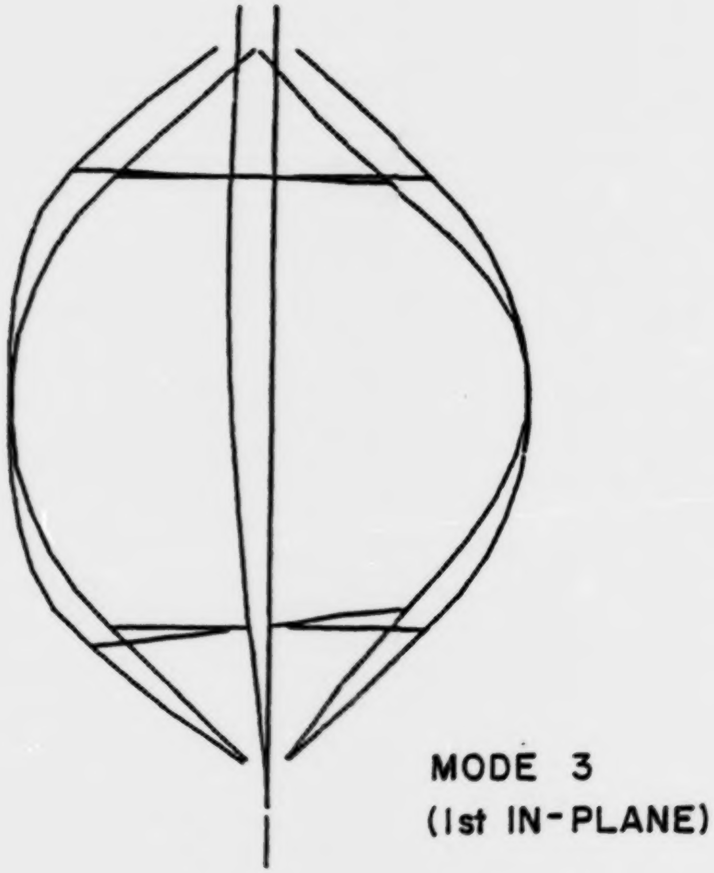
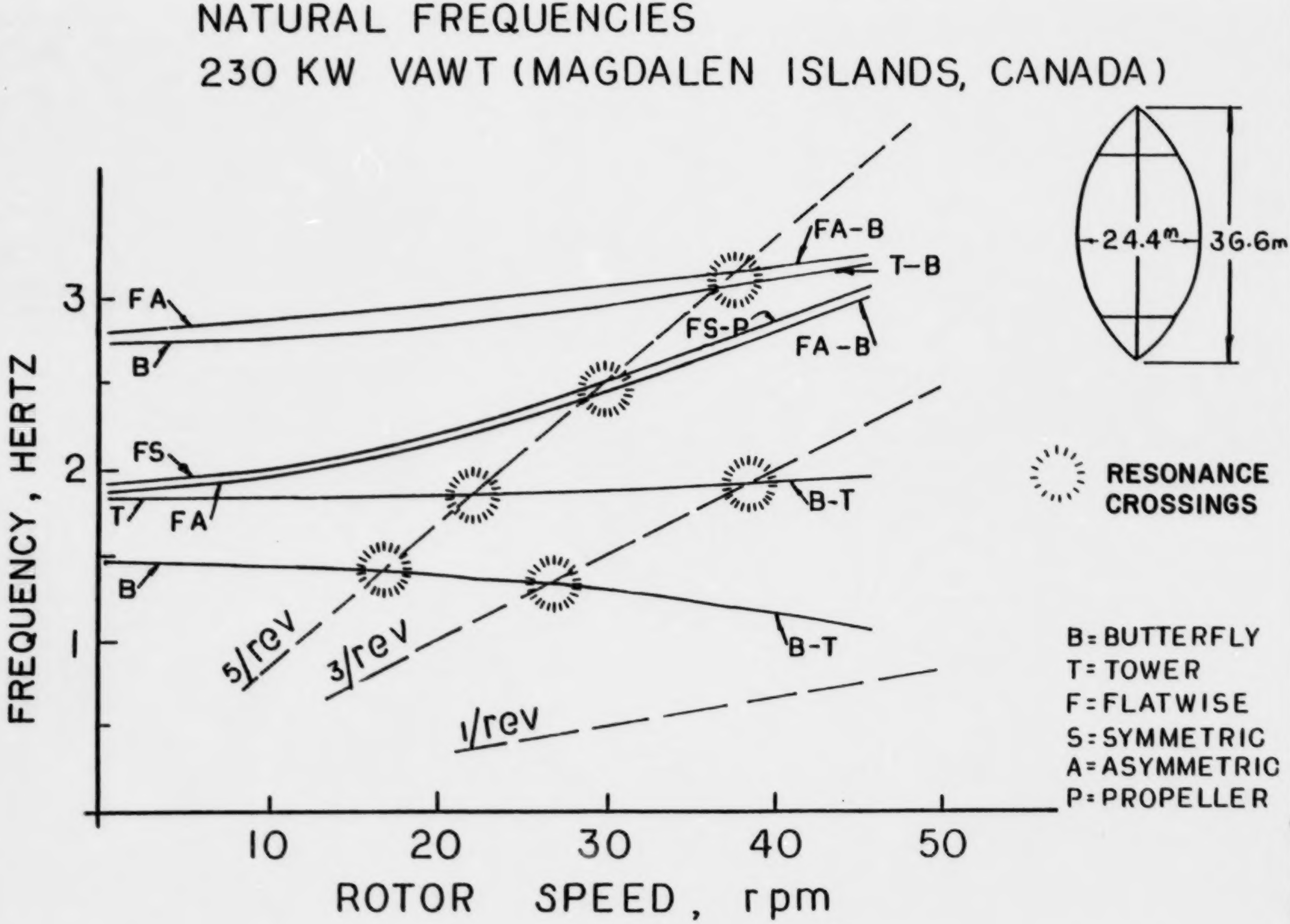

MODE 3
(1st IN-PLANE)

Fig. 11. CALCULATED DISTORTION OF VAWT ROTOR (exagerated computer plot)

Fig. 12


NATURAL FREQUENCIES
230 KW VAWT (MAGDALEN ISLANDS, CANADA)
24.4m
36.6m
FA
B
FS
T
FA
B
FA-B
T-B
FS-B
FA-B
B-T
B-T
5/rev
3/rev
1/rev
RESONANCE CROSSINGS
B = BUTTERFLY
T = TOWER
F = FLATWISE
S = SYMMETRIC
A = ASYMMETRIC
P = PROPELLER
FREQUENCY, HERTZ
3
2
1
10
20
30
40
50
ROTOR SPEED, rpm

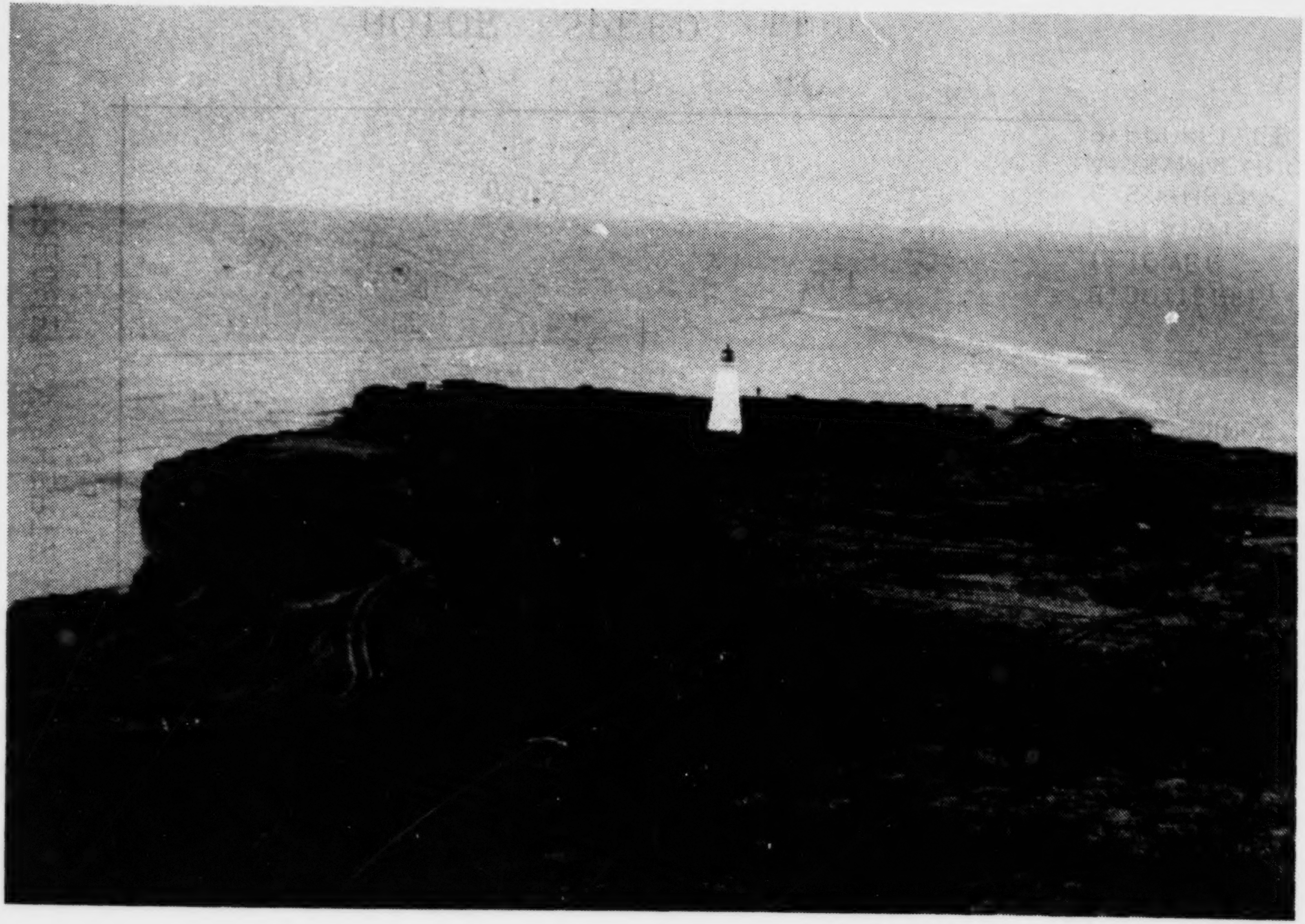


Fig. 13 Aerial View Of Atlantic Wind Test Site, P.E.I.

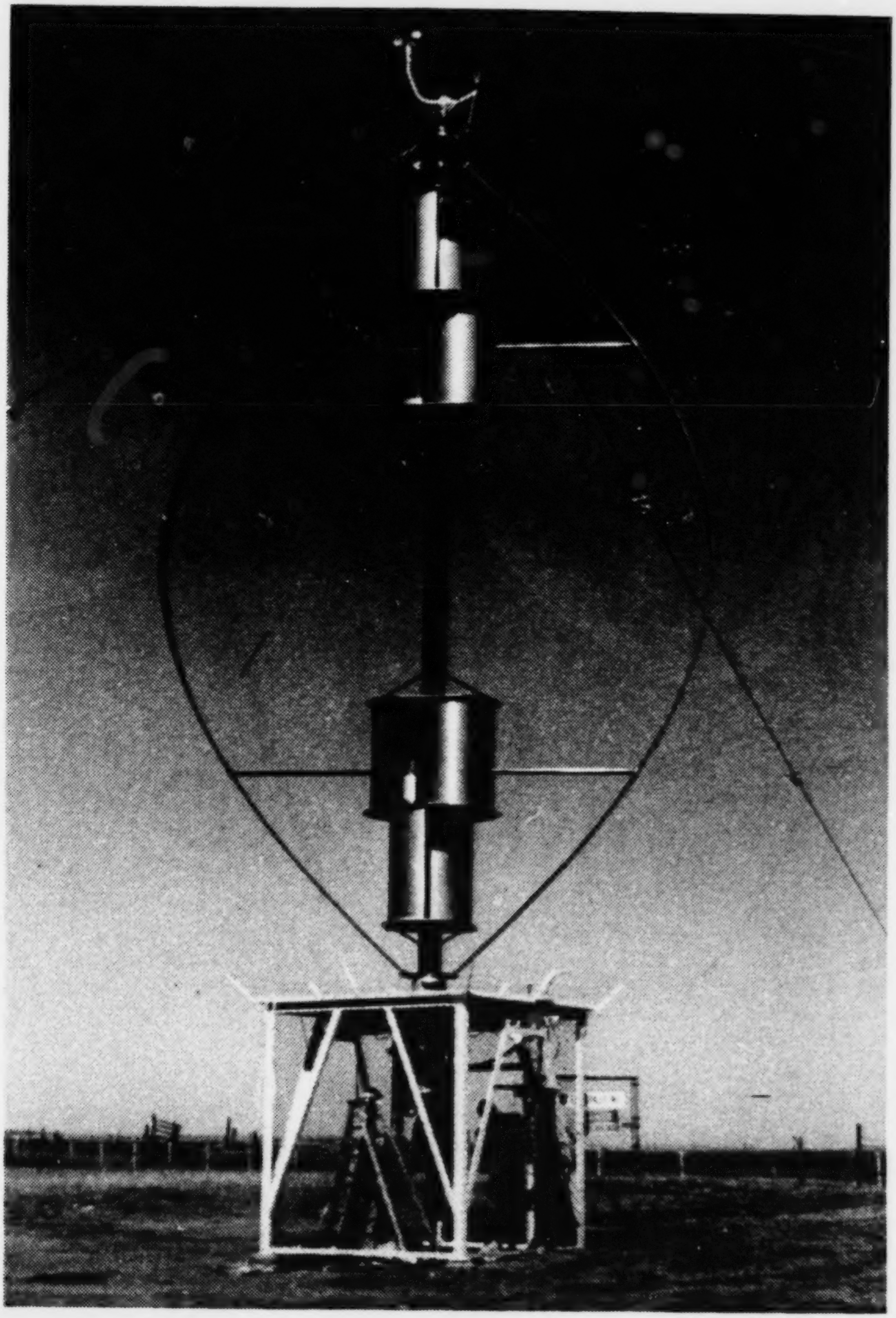


Fig. 14 5 kW Autonomous VAWT For Battery Charging

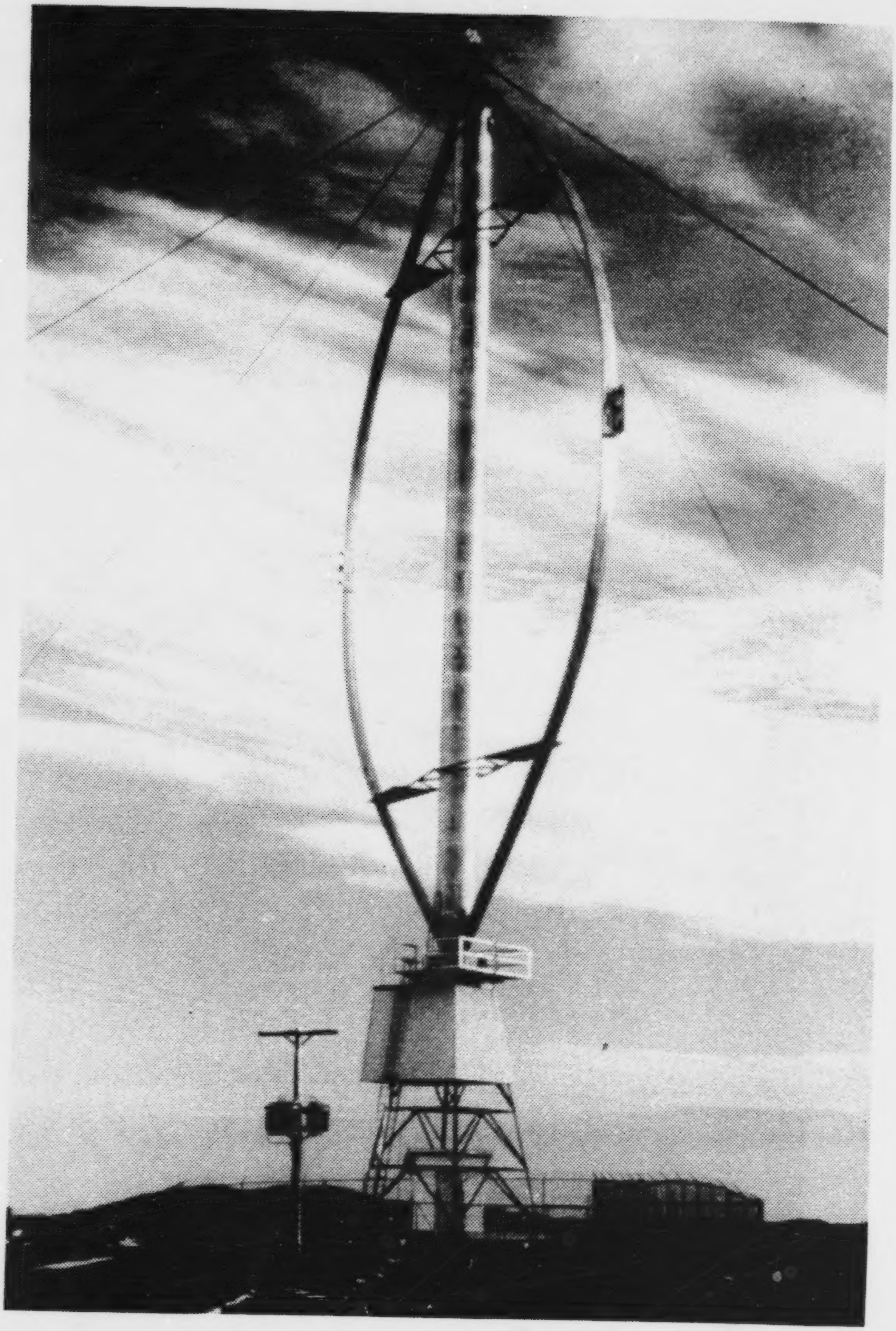


Fig. 15. 230 kW Experimental Grid-Coupled VAWT
Iles de la Madeleine, Québec

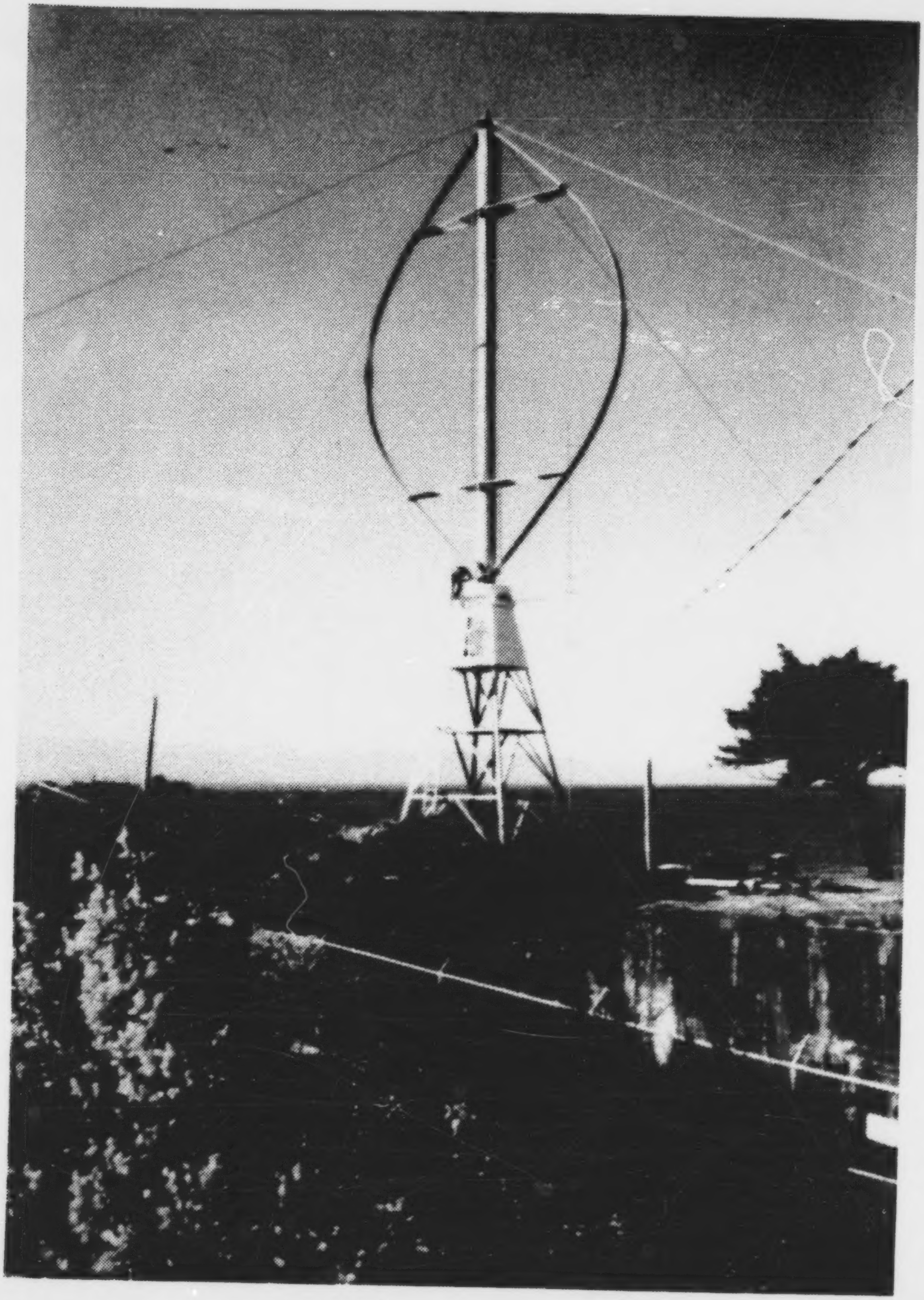


Fig. 16. 50 kW Experimental Grid-Coupled VAWT
Christopher Point, B.C.

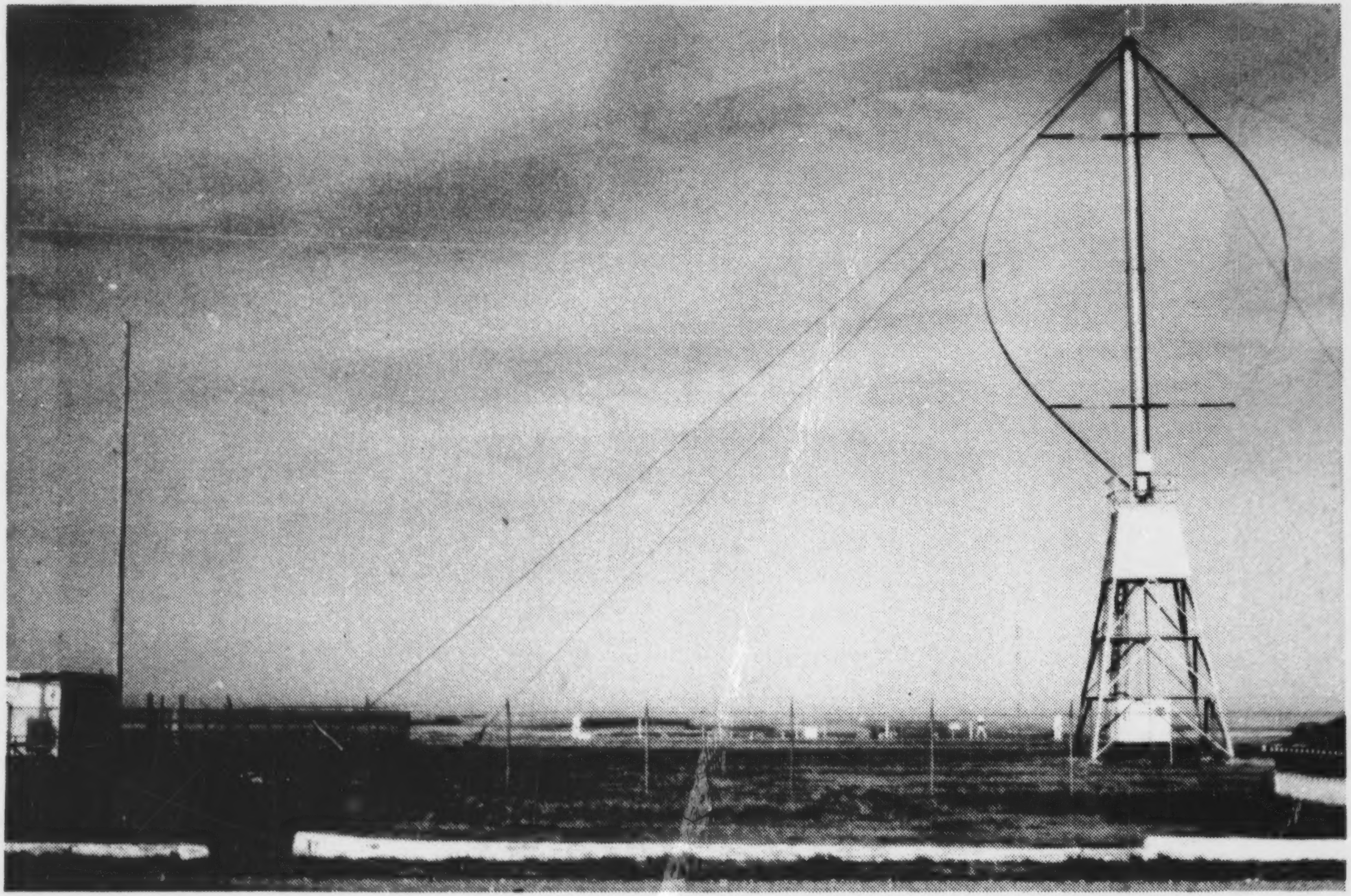


Fig. 17. 50 kW Experimental Grid-Coupled VAWT, Swift Current, Sask.

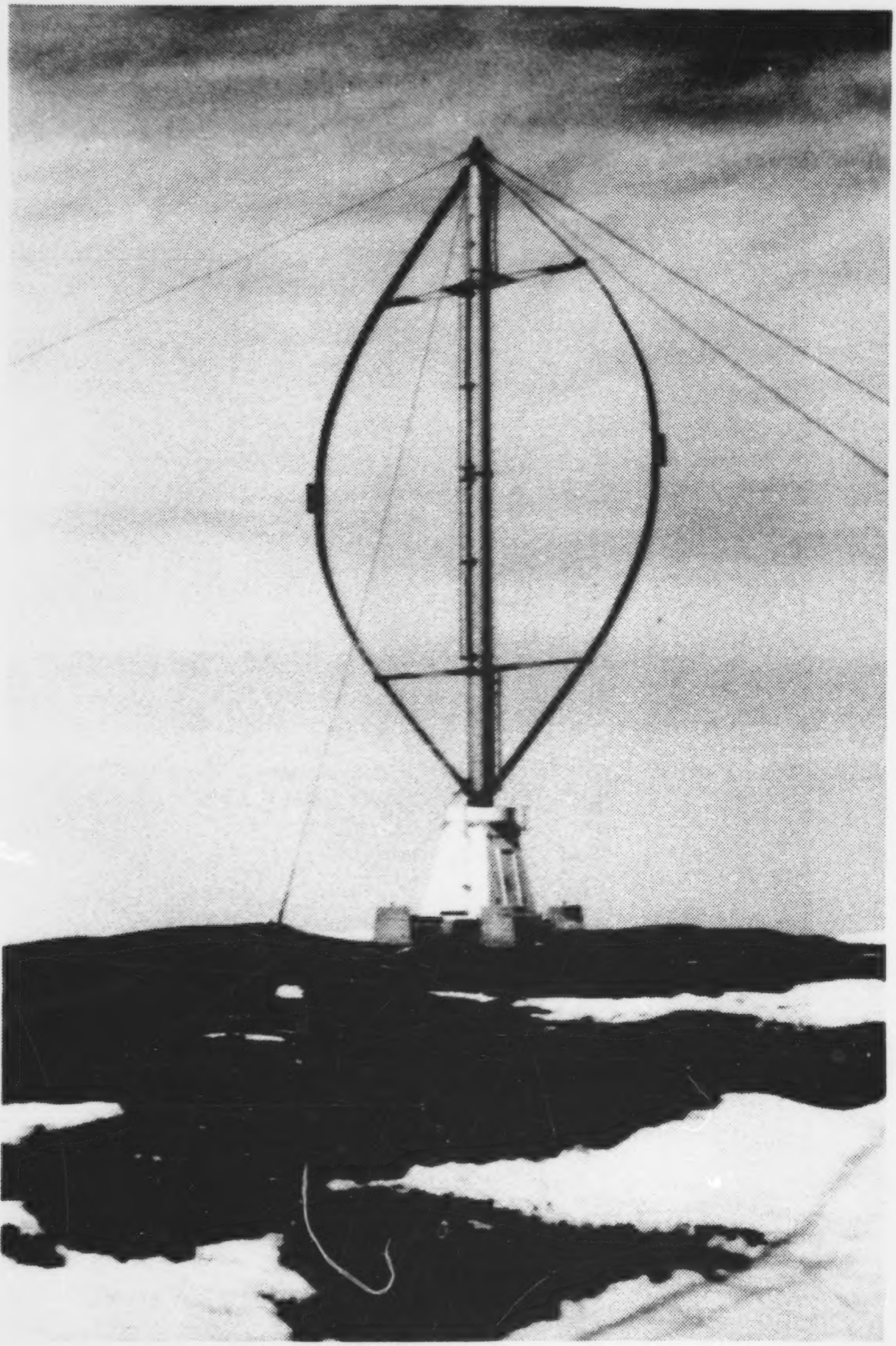


Fig. 18. 50 kW Experimental Grid-Coupled VAWT
Churchill, Manitoba

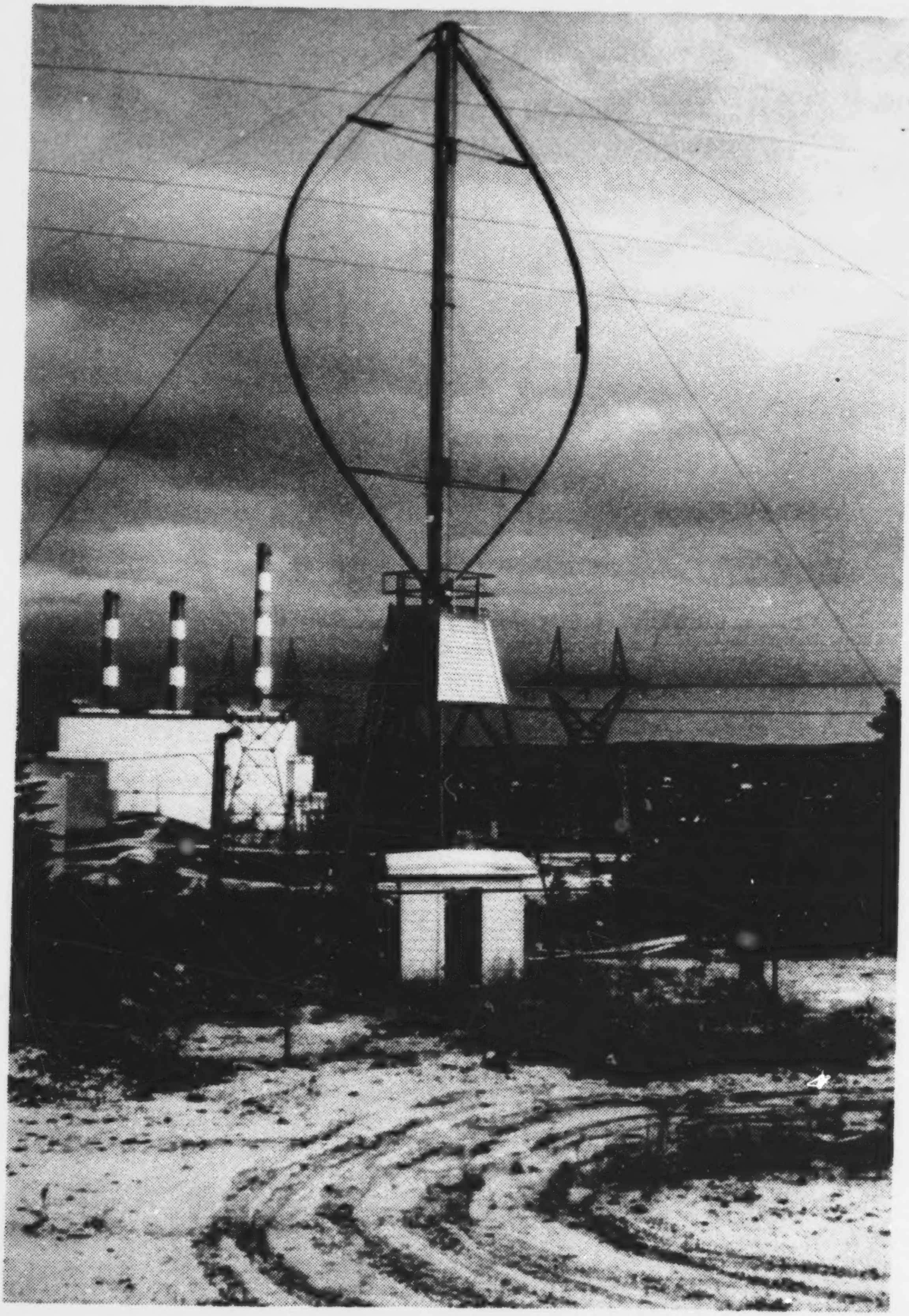


Fig. 19. 50 kW Experimental Grid-Coupled VAWT
Holyrood, Newfoundland

NRC WIND ENERGY R&D PROGRAM

50 kW VAWT FIELD TRIAL SYSTEMS – December 31, 1984*
date

LOCATION	PARTNER	START OF GEN. SERVICE	OPERATING HOURS		NET OUTPUT MWh	CURRENT STATUS
			TOTAL	GEN.		
HOLYROOD, NFLD (I)	NL HYDRO	JUNE 78	4,582	3,015	21.6	Removed for study NOV 81
HOLYROOD, NFLD (II)	NL HYDRO	MAY 82	8,090	6,490	73.0	OPERATIONAL
SWIFT CURRENT, SASK	SASK POWER	AUG 80	6,260	6,190	54.0	OPERATIONAL
CHRISTOPHER POINT, BC	BC HYDRO	MAR 81	9,460	7,550	122.0	OPERATIONAL
CHURCHILL, MAN	CHURCHILL RESEARCH CENTER	NOV 81	10,570	8,790	116.0	OPERATIONAL
		TOTALS	38,962	32,035	386.6	

*Estimated year end data
prepared as of 31 October 1984

Fig. 20.

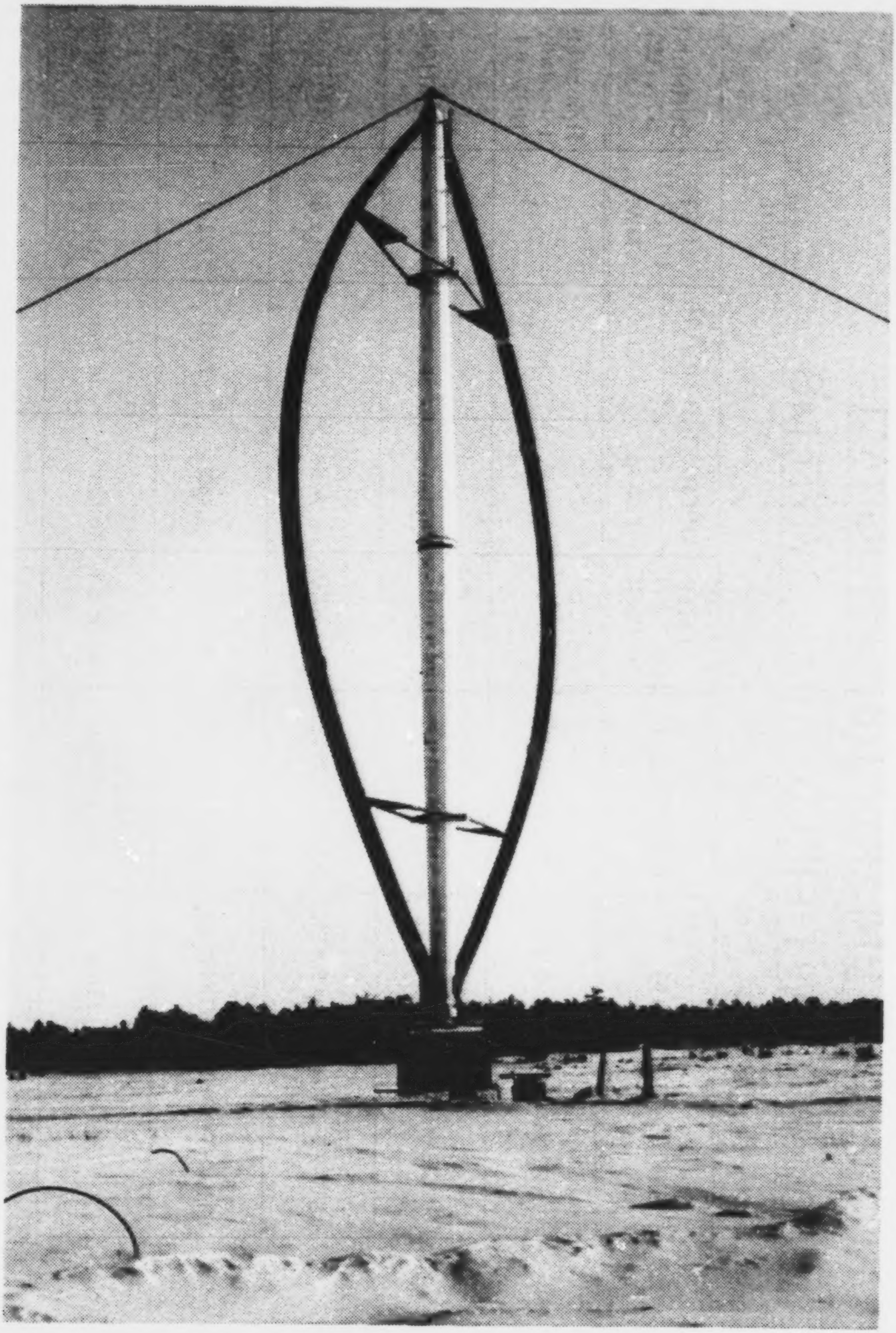


Fig. 21. 500 kW Prototype VAWT, Atlantic Wind Test Site

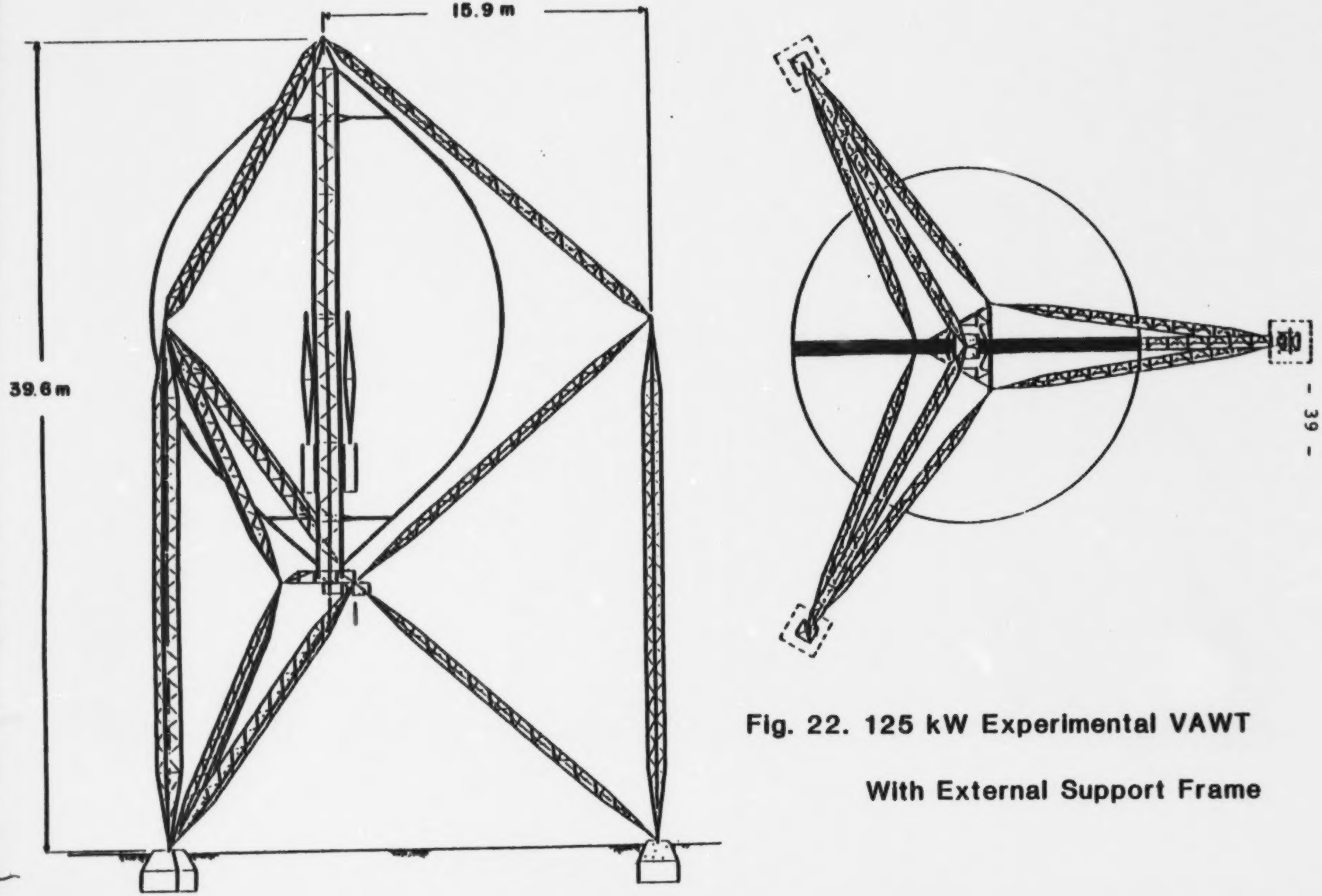


Fig. 22. 125 kW Experimental VAWT

With External Support Frame

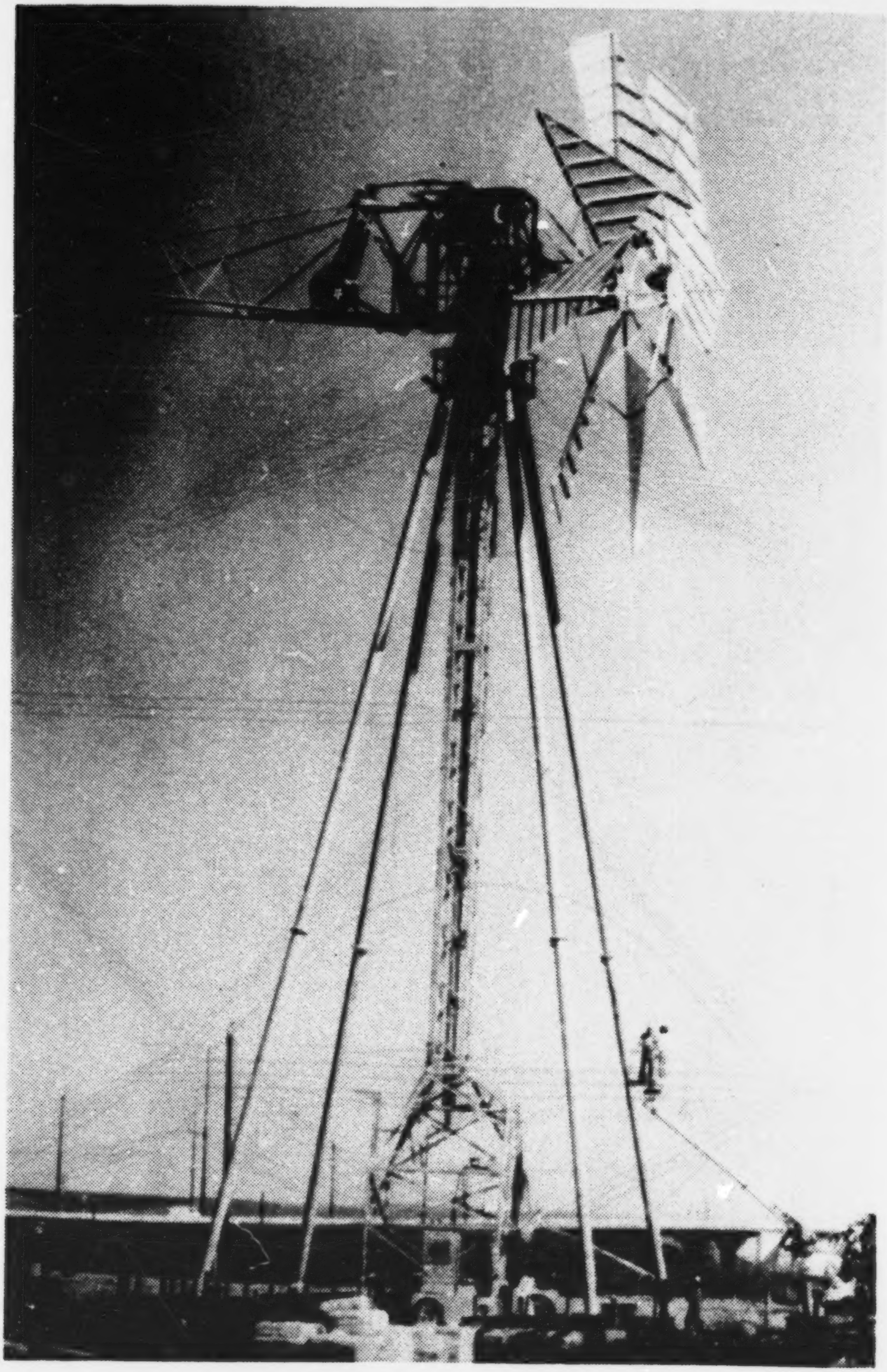


Fig. 23 DELTX 100 m^3/min Irrigation Windpump

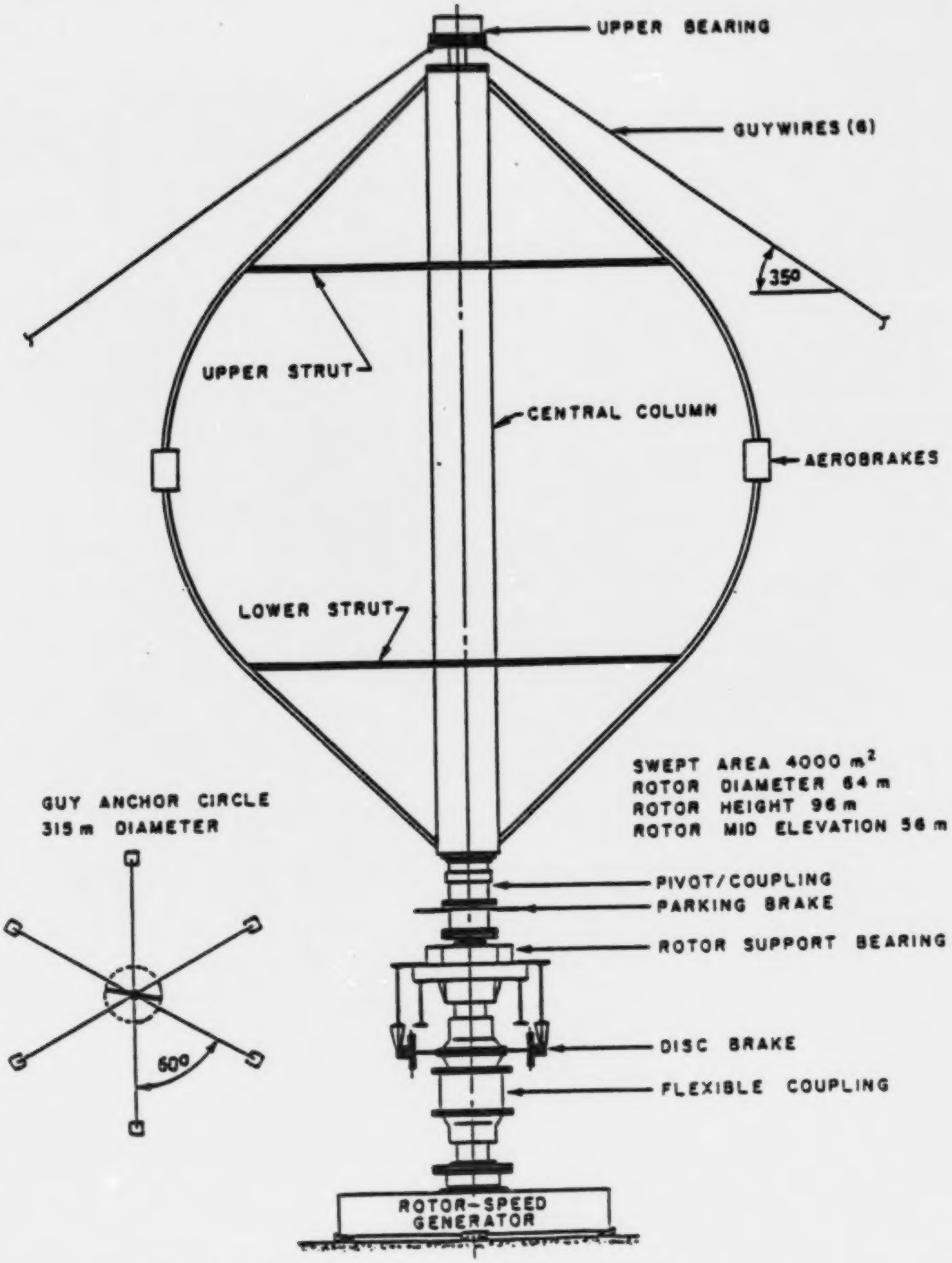

UPPER BEARING
GUYWIRES (6)
35°
UPPER STRUT
CENTRAL COLUMN
AEROBRAKES
LOWER STRUT
SWEPT AREA 4000 m²
ROTOR DIAMETER 64 m
ROTOR HEIGHT 96 m
ROTOR MID ELEVATION 56 m
GUY ANCHOR CIRCLE
315 m DIAMETER
60°
PIVOT/COUPLING
PARKING BRAKE
ROTOR SUPPORT BEARING
DISC BRAKE
FLEXIBLE COUPLING
ROTOR-SPEED GENERATOR

Fig. 24. EOLE - 4 MW VAWT General Configuration

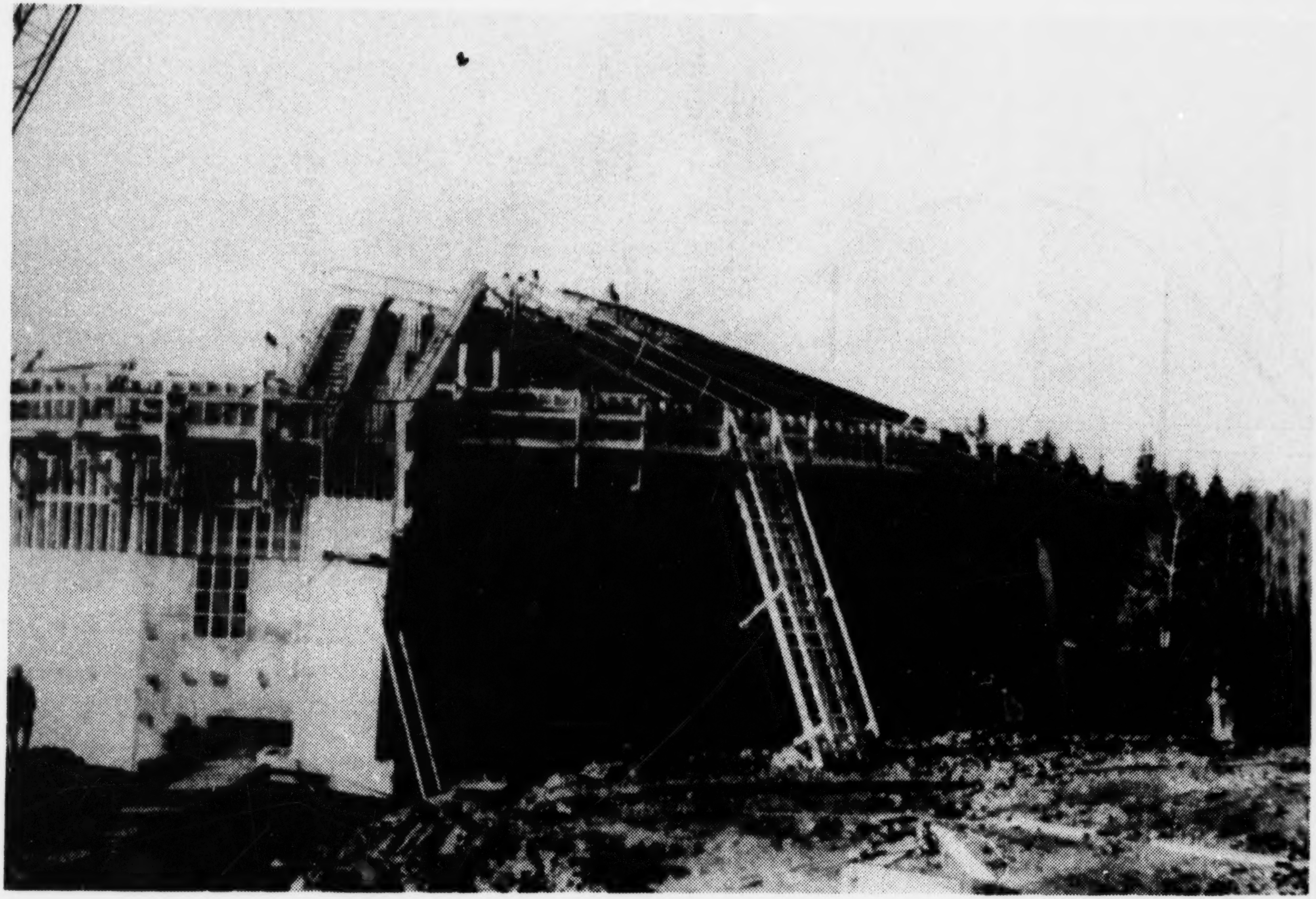


Fig. 25. EOLE – Rotor Support Building Under Construction

APPLICATIONS

SUMMARY

Testing of the DAF Indal Series 6400-500 kW VAWT

L. Schienbein
DAF Indal Ltd.

For Presentation at the Seventh Annual Wind Energy Symposium
Toronto, October 10-11, 1984

Two DAF Indal Series 6400 - 500 kW VAWTs were installed in 1983. The 500 kW VAWT was designed and developed by DAF Indal as a commercial unit for both wind farm and hybrid applications. The first unit of this series is owned by the Southern California Edison Company and is presently completing acceptance testing near Palm Springs, California, while the second unit is owned by the National Research Council of Canada and is completing acceptance testing at the Atlantic Wind Test Site in Prince Edward Island, Canada.

Both units are extensively instrumented and a significant amount of operating data has already been gathered. As of October 19, 1984, the Southern California Edison unit was in fully automatic and unattended operation and had accumulated 1340 hours of on-line operation and generated 216,960 kWh. Wind conditions available to date have permitted the VAWT to reach power outputs well in excess of 500 kW. Structural load and structural dynamic test data have been acquired for average wind speeds of up to 50 mph with gusts to 60 mph. The data are in good agreement with predictions.

The test program for each VAWT includes in plant power module tests, commissioning, preacceptance and acceptance tests. The overall objectives of the test program are:

(1) To verify that all VAWT subsystems, critical components and assemblies function as required to achieve the system availability and maintainability requirements.

(2) To verify that the structural stresses meet the design criteria and to confirm that structural vibration modes are not excited.

(3) To establish the power output performance curve.

(4) To verify correct and reliable operation of the control and protection devices, power factor correction capacitors and the brakes.

The test program included a major structural inspection of the Southern California Edison VAWT in July and August, 1984 after about 900 hours of operation. The rotor was dismounted for the inspection, which included non destructive tests, disassembly of some blade splices and root connections and bolt torque checks. No significant problems were revealed and the machine was placed back in automatic operation on August 31.

This paper describes the elements of the test program and the objectives of each phase. Significant test results are presented and discussed; particular emphasis is placed on recent performance, structural and reliability test results and the progress that has been made in meeting the objectives of the work.

TESTING OF THE DAF INDAL SERIES 6400-500 KW VAWT

Lawrence Schienbein, DAF Indal Ltd.

I have taken the liberty of changing the topic of my presentation because I wanted to cover more of the aspects of the test programme running from the factory through the testing on in the field.

This morning, I will discuss the background to the development of the 500 kilowatt machine, the objectives of our test programme, the method that we have used in the testing, some of the interesting and important results of the testing and some conclusions.

The development of the 500 kilowatt machine began in 1981 with the conceptual design. In 1983, two prototype units were installed (See figure 1). The first one was installed near Palm Springs. Up to October that machine had operated for over 1300 hours. The second unit has operated for about 500 hours at the Atlantic Wind Test Site. In addition to the test programme that we are engaged in at Palm Springs, the Electric Power Research Institute in the U.S.A. has a two-year test and evaluation programme underway on our unit. Our current plans are to deploy the third unit, or the third sister machine of this series of prototype units, with some changes to improve both reliability and performance.

The decision to develop the 500 kW VAWT was based on two factors. First of all, we as a company had a high degree of confidence in our wind turbine technology, as a result of the 50 kilowatt development programme. Secondly, in 1981 we recognized that two key markets for wind turbines were emerging or developing rather quickly, the wind farm and the remote community markets.

We chose the 500 kilowatt rating because we are at first pursuing markets where the wind resource is very good, wind sites with average wind speeds in the 8 meter per second and above range. We had experience with building and designing a rotor of about 600 square meters through our work with the Magdalen Island machine, and in addition we were confident of the features that we had innovated on the 50 kilowatt machine. As a result of those three factors, we chose a rotor size equivalent to that of the Magdalen Island machine and uprated it to optimize the output in the high wind speed regimes.

The design features that are incorporated on the 500 kilowatt machine follow directly through from the 50 kilowatt machine. The hydraulic rotor support permits automatic guy tensioning. We developed our own control logic and the combination bull gear-disc brake system. We applied a centrifugally-actuated hydraulic valve to the 50 kilowatt machine and demonstrated that we could have the same overspeed protection as could be available from air brakes. Finally, we demonstrated on the 50 kilowatt machines that the concept of factory assembling and testing the power train, switch gears and controls could lead to reduced installation costs and higher reliability.

The key features of the 500 kilowatt machine, are as follows (See figure 2):

(1) The hydraulic upper bearing which takes up most of the guy tensioning function.

(2) The rotor is 120 feet by 80 feet, identical to the Magdalen Islands size.

(3) The rotor has struts at the 20 per cent and 80 per cent rotor height positions, similar to the Magdalen Island machine.

(4) The main coupling and hydraulic supports

(5) The single stage transmission with two pinions, driving two 260 kilowatt generators.

(6) The hydraulic power unit which supplies the high pressure oil to both bearings and another pump which sends the lubricating oil to the pinion mesh.

The main objective of our test and evaluation programme is design verification and demonstration. Testing begins in the factory. We operated both unit one and unit two power modules for continuous periods of between 12 and 24 hours at the factory to evaluate the hydraulic system and to check out the controls. The purpose of the commissioning process in the field is to bring the unit to the operating state. Pre-acceptance tests are the heart of the engineering evaluation before the machine is released for acceptance testing. During the pre-acceptance tests we monitored a number of parameters on the machine, stepping the cut-out windspeed up successively to the design cut-out windspeed. Having evaluated the data, principally the structural data, the machine was cleared for acceptance testing. During the acceptance test, with our instrumentation operating, we can gather as much data as we want. The ongoing monitoring and evaluation will be carried out principally by others. We will share in all of the data.

The emphasis on structural data relates to evaluating the validity of our forced dynamic response prediction methods. We also want to verify our ability to predict natural frequencies. Our structural testing does include major and minor structural inspections.

We are interested in establishing the power output performance and also the power quality. For a grid-connected induction generator type machine, the power quality includes power factor and power ripple.

The protection system logic must operate correctly. The system also requires 100 per cent reliable operation of the hardware, which includes transducers. Control system evaluation includes the ability of the logic to do its job (performance) and the reliability of the hardware itself.

The brakes are a critical element for any wind turbine. In our system, the brakes are part of both the regular braking system and the emergency braking system. Because the two systems have this element in common, it is essential that the brakes operate with 100 per cent reliability.

During the testing of the two machines, we have the opportunity to check out the reliability and maintainability of certain sub-systems; we have an opportunity to determine whether we can carry out maintenance in the way that we thought we could. Also, while the two machines are in operation, we have the opportunity to insert special product development tests.

Most of the test data that I will present is from the Southern California Edison machine. We established a joint test programme with that company in 1982. Southern California Edison in turn contracted with Sandia National Laboratories to obtain a computer-based data acquisition system for use at Palm Springs and has also contracted with Sandia Labs for data analysis. DAF Indal has provided most of the instrumentation for the project and a technician to gather and sort data.

The Electric Power Research Institute has independently undertaken a two year evaluation of our machine and has contracted Southern California Edison Company to carry out most of the tests that are either contemplated or are already completed. Both the wake and noise measurement studies have been completed. Fatigue life assessment is the largest single work package in the programme; it is now just getting under way. Power quality and performance have largely been evaluated and the reliability and maintainability will be documented over the next two years. This is a very important and worthwhile programme for us because it is a third party evaluation of our machine.

The following is a description of our data acquisition method. We have the ability to record data continuously using an endless loop programme. Our basic format for data acquisition is a twenty minute time block, or segment; and we gather data at ten samples per second on about 48 channels. We then group these twenty minute segments by five mile per hour increments of wind speed. Finally these data are transferred to a disc for analysis, such as: binning, spectral analysis and analysis of time series. We can sample at rates of up to 100 Hz. This is very useful for structural dynamics work.

A schematic of the data acquisition system is shown in figure 3.

The original strain gauges have now been supplemented by more gauges which have been applied for the long-term fatigue assessment. The data acquisition system was developed by Sandia Labs. It is based on the HP-1000 computer. There are about six units like this in the field, in service with different vertical axis wind turbine test programmes.

We have good structural data for steady windspeeds up to 50 mph with gusts to about 65 mph. We have determined that the natural frequencies that have been measured are in very good agreement with those predicted. We have discovered that certain transient electrical conditions can lead to very high loads being imposed on the power train.

In July, carried out a complete inspection of the rotor after 900 hours of operation. The rotor was taken down and was on the ground for about six weeks. We carried out non-destructive tests of critical parts of the rotor and the coupling. We inspected blade joints. We disassembled one root connection and one blade splice connection. We checked every bolt torque on the rotor. We discovered no significant problems. There was no evidence of damage or accelerated fatigue and in particular, there was no evidence of failure of any of the joints. As far as we know, this machine has experienced winds to 90 mph in the parked condition. Our design is for 150 mph. We have been fortunate enough to have had operating conditions where the machine has experienced 65 mph winds.

I would like to spend a few minutes looking in detail at some of the stress data that we have gathered and compare it to the theoretical predictions. Our theoretical predictions are derived from a finite element model based on NASTRAN (See figure 4). We introduce into the model the aerodynamic loads, generated by a double multiple stream tube programme which can be operated with and without dynamic stall.

The strain gauge locations are shown in figure 5. The B1 location is near the lower root and the B3 location is just above the lower strut. The B3 location is one of the most highly stressed portions of the blade.

Figure 6 is a stress spectral distribution for the B1 position leading edge of the blade (upper left). The upper right spectrum is for the B3 location, again the leading edge. The peaks for the B3LE location are at one per rev and three per rev. For the B1LE location there are three peaks: one, two and three per rev.

At the B3LE location, the Zero P component of the stress is very close to that predicted (See figure 7).

The predicted one per rev component values of the stress are less than the measured values (See figure 8).

The predicted two per rev component values are greater than those measured. For this component, the absolute values are so low that measurement resolution becomes a key factor (See figure 9).

The three per rev stress is the most important component. Figure 10 shows that the predicted stresses are somewhat higher than those measured, where the blades begin to stall.

Figure 11 show the stresses for the B3LE location in the form of the standard deviations. The standard deviation is believed by some to be a fairly good measure of the fatigue damage that is being incurred at different windspeeds. The standard deviations of predicted and measured stresses are in quite good agreement.

At the B1LE location, the one per rev and two per rev predicted versus measured stresses are in good agreement (See figures 12 and 13). The dynamic stall behaviour that we predicted does not seem to be showing up in the actual data.

That point is shown most clearly with the three per rev behaviour of the machine at the B1LE location (See figure 14). Here again the agreement between measured and predicted standard deviation of stress range is quite good (See figure 15).

The maximum average stress that we have observed in the blades is about 3500 to 4000 psi, at the B3 trailing edge location. Most of the other blade stresses observed are in the 2000 psi range. In the steel components, the column and the struts, the maximum stresses that have been observed are about 2000-2500 psi. These are all quite low values. The fatigue life of the machine should be 20 years, as projected.

The measured power output is in quite good agreement with what we originally predicted about two years ago (See figure 16). It is very difficult to determine the performance of the machine at very high power outputs because the winds just do not blow long enough in that range. It is difficult to know whether what we are seeing at the high end of the performance curve is a folding over, or stepping effect, due to the lack of data.

We have observed power outputs well in excess of 520 kilowatts on several occasions, so there is no question about the machine reaching its rated output. The power ripple for the machine is about thirty per cent with two generators on line. Power ripple is defined as the amplitude of the ripple divided by the mean value. With a single generator the damping effect is changed and the ripple is halved. The power factor with capacitors has been measured to be .9 for power outputs above about 100 kilowatts.

Figure 17 is a time series of actual power output at average powers in the 450-500 kilowatt range and illustrates the two per rev power ripple. Windspeed is plotted at the top. The windspeed at the equator was about 40 to 45 mph.

Figure 18 is a plot showing the reactive power, the real power and the windspeed. As the power output changes so does the reactive power as expected. For outputs of about 100 kilowatts, reactive power is on the order of 30 kVA.

We have had many trips of our centrifugal dump valves. We are satisfied with the operation of these valves but we have a new design that we are about to test which we think will be better in terms of being more easily reset and more predictable in the tripping speed. So far, these valves, which were perfected on the 50 kilowatt machine, have never failed to operate.

The protection logic is sound. We have demonstrated some loss of load shutdowns at Palm Springs. These loss of load tests have been restricted to pulling the main breaker on the machine. That is about as far as one can go without isolating a complete substation.

We have demonstrated reliable operation of the controls. We have determined that some modifications are required to handle the high ratio of power output to inertia of this machine. During start-up of the machine when the motor is taken off line, the rotor will accelerate very rapidly. It is essential that the generators come back on line very close to synchronous speed. If they do not, very high transient loads can be imposed on the transmission. The control system must anticipate when the machine is going to cross synchronous speed. With a hard-wired type of logic this problem is somewhat difficult to handle. About one year ago we began work on a micro-processor based control system. We have completed our bench testing of the system and are ready for field tests.

We have achieved our design braking torque, about 200,000 foot-pounds under emergency conditions. That is about two and one half times the rated torque of the machine. We have demonstrated reliable operation of the brakes in both normal and emergency conditions. As a result of our testing over a year ago, we determined that we could reduce the intensity of braking through a "soft brake system".

Figure 19 is a plot of the soft brake system in operation. It is not necessary to apply the full 200,000 foot-pound braking capacity under normal stops. It can be applied for a period of one or two seconds. Then the torque can be reduced for the balance of the braking period. This is accomplished by changing the hydraulic support pressure for the rotor during the latter part of the braking. With the microprocessor controller, braking logic can be 'tuned' to more closely match the braking torque to the rotor torque.

The main reliability problems have been related to the hydraulic system. That is not too surprising because the hydraulics are the unique part of the system. The lower rotor bearing stub shaft developed a leak. That problem was corrected.

The original transmission pinions were found to be too soft. They were replaced with harder pinions. The rest of the problems have been of a more minor nature. These include dump valve nuisance trips. We have solved problems related to gear box lubrication oil leakage, out of adjustment tachometer sensors, a level valve stem break due to mechanical failure, and a lubrication oil flow switch susceptible to mechanical vibration.

We have concluded that the design is fundamentally sound. We have uncovered some component design specification and manufacturing faults. Some component specifications must be upgraded. A microprocessor based control system is required. The performance has been verified to about 400 kW. Structural stresses are quite low and the natural frequencies are as predicted. We understand, as do others, that we have to minimize the number of moving parts on the rotor. We have the opportunity on unit three to improve the reliability and the power output by making changes based on the test results.

Thank you very much.

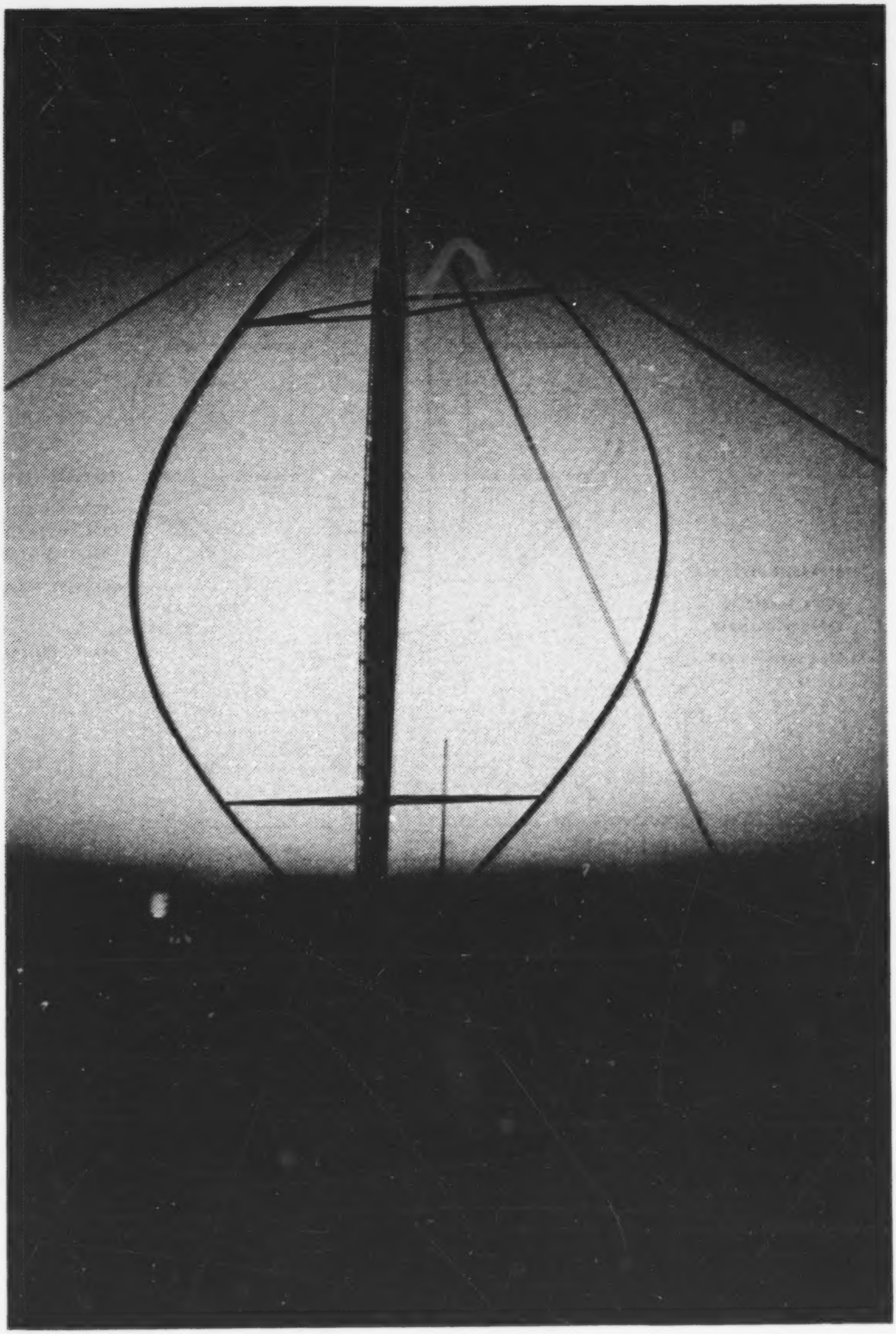


Figure: 1

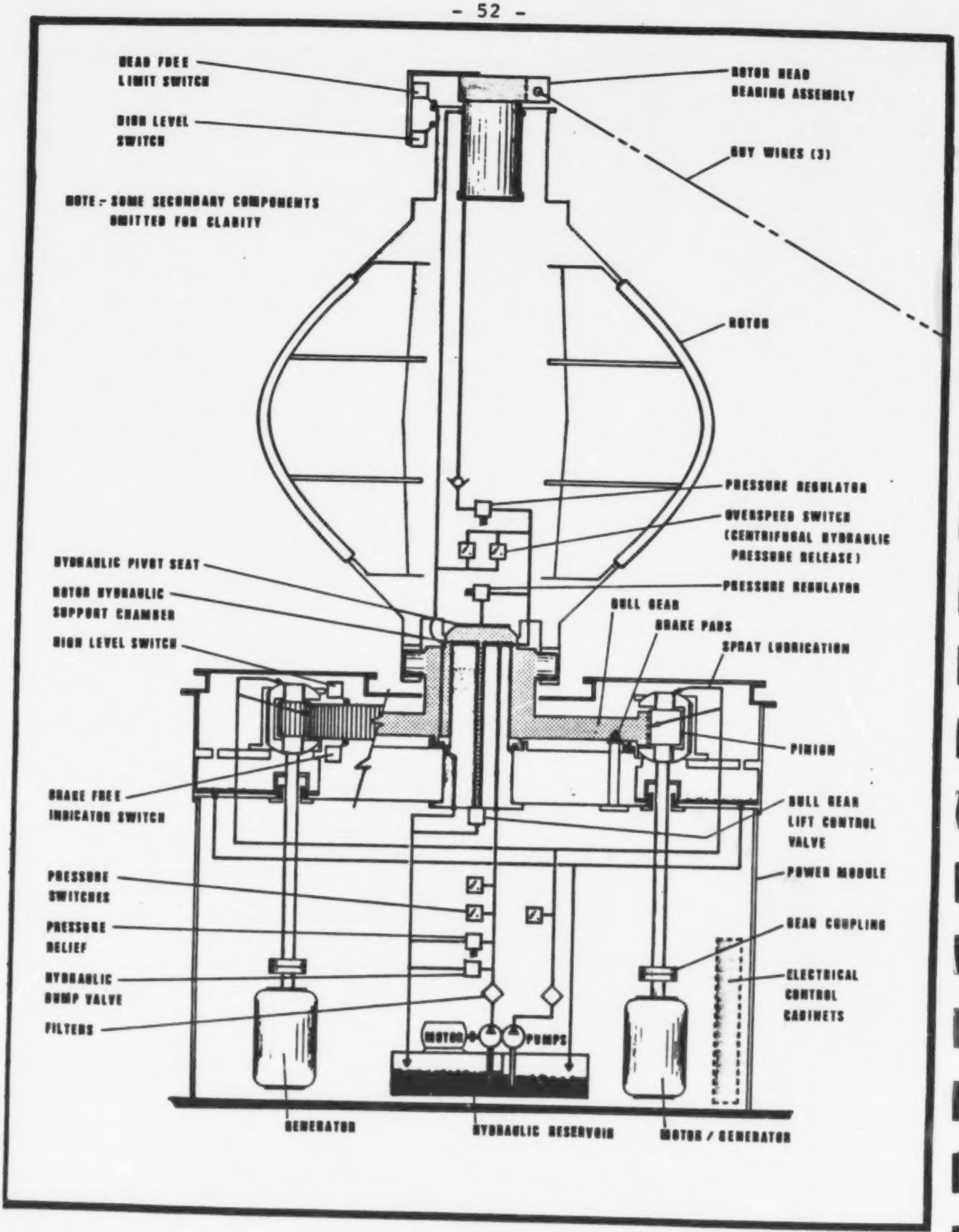

HEAD FREE LIMIT SWITCH
HIGH LEVEL SWITCH
NOTE:- SOME SECONDARY COMPONENTS OMITTED FOR CLARITY
ROTOR HEAD BEARING ASSEMBLY
GUY WIRES (3)
ROTOR
PRESSURE REGULATOR
OVERSPEED SWITCH (CENTRIFUGAL HYDRAULIC PRESSURE RELEASE)
HYDRAULIC PIVOT SEAT
ROTOR HYDRAULIC SUPPORT CHAMBER
PRESSURE REGULATOR
BULL GEAR
BRAKE PADS
HIGH LEVEL SWITCH
SPRAY LUBRICATION
PINION
BRAKE FREE INDICATOR SWITCH
BULL GEAR LIFT CONTROL VALVE
POWER MODULE
PRESSURE SWITCHES
PRESSURE RELIEF
GEAR COUPLING
HYDRAULIC DUMP VALVE
ELECTRICAL CONTROL CABINETS
FILTERS
MOTOR
PUMPS
GENERATOR
HYDRAULIC RESERVOIR
MOTOR / GENERATOR

Figure: 2

Schematic of the DAF Indal Series 6400 - 500 kW VAWT

DAF INDAL SERIES 6400-500 kW VAWT
PALM SPRINGS, CALIFORNIA
INSTRUMENTATION AND DATA ACQUISITION

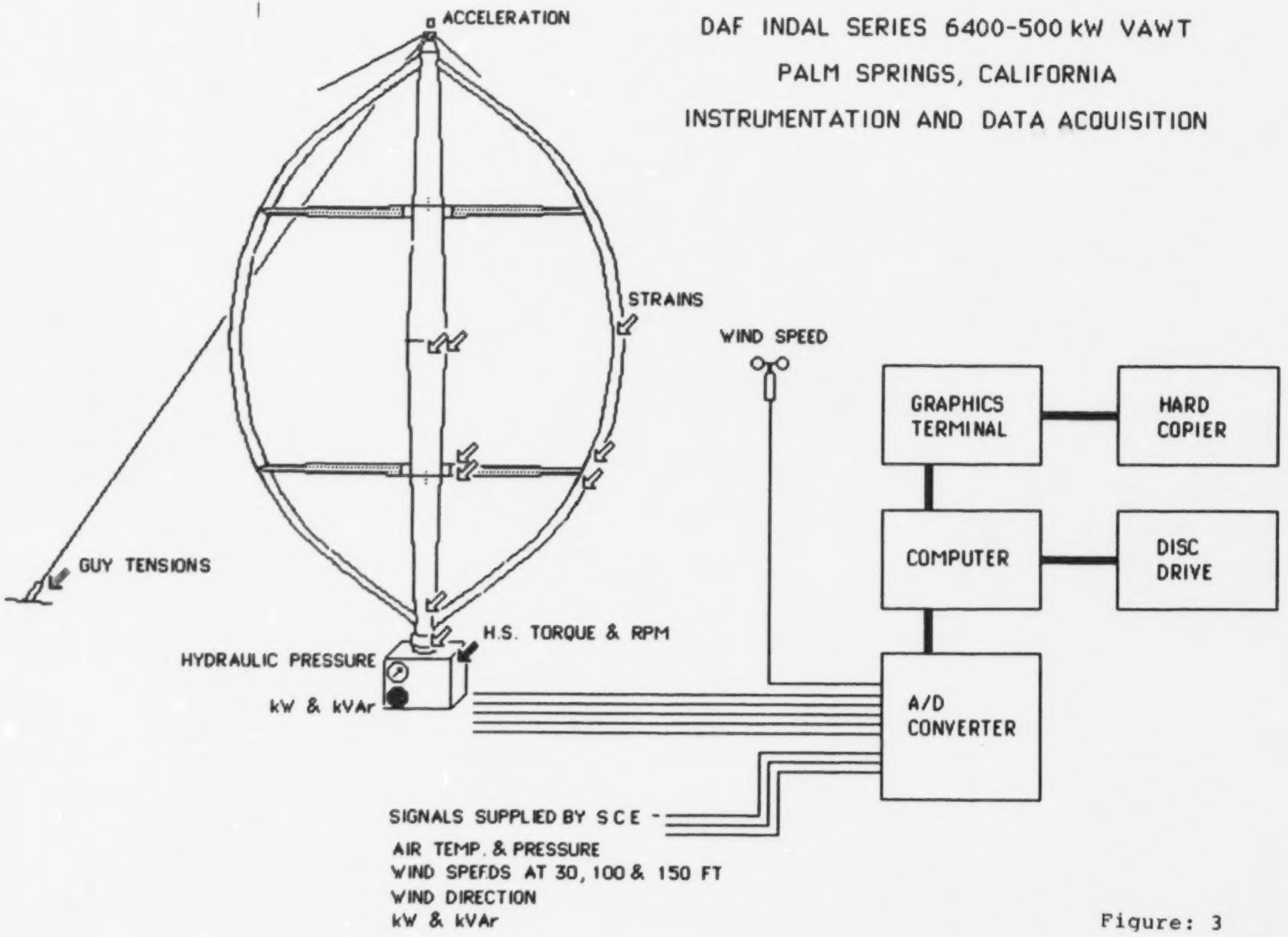
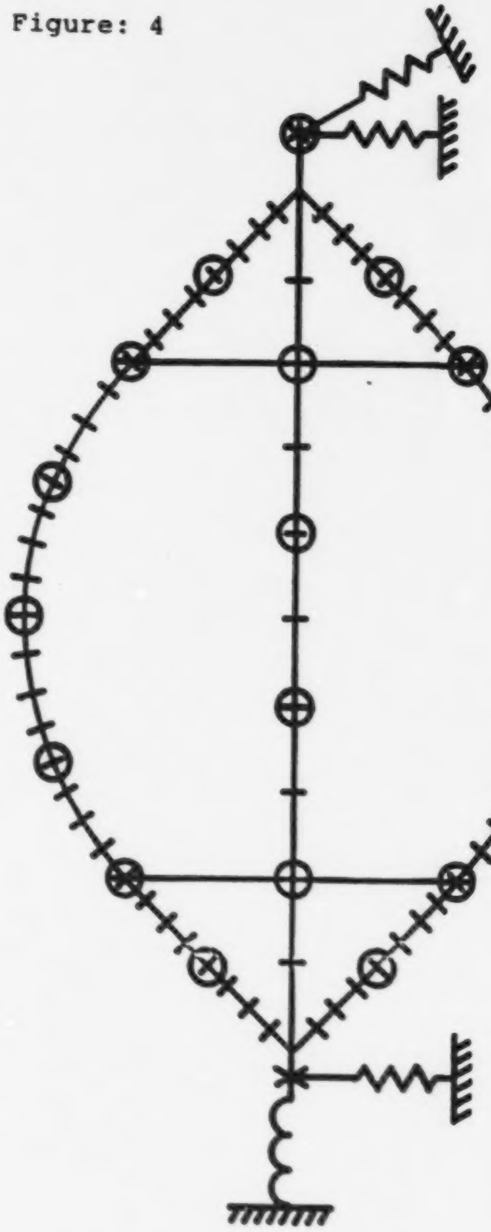

ACCELERATION
STRAINS
WIND SPEED
GRAPHICS TERMINAL
HARD COPIER
COMPUTER
DISC DRIVE
GUY TENSIONS
H.S. TORQUE & RPM
HYDRAULIC PRESSURE
kW & kVAr
A/D CONVERTER
SIGNALS SUPPLIED BY S C E -
AIR TEMP. & PRESSURE
WIND SPEEDS AT 30, 100 & 150 FT
WIND DIRECTION
kW & kVAr

Figure: 3

FINITE ELEMENT MODEL OF VAWT ROTOR

Figure: 4



ALL ELEMENTS: 3-DIMENSIONAL BEAM ELEMENTS
ALL NODES: 6° OF FREEDOM

—┼— FINITE ELEMENT NODE
—⊖— "MASTER" NODE (3° OF FREEDOM)
—✕— CONCENTRATED MASS
∿∿∿ SCALAR SPRING
⌒⌒⌒ TORSIONAL SPRING

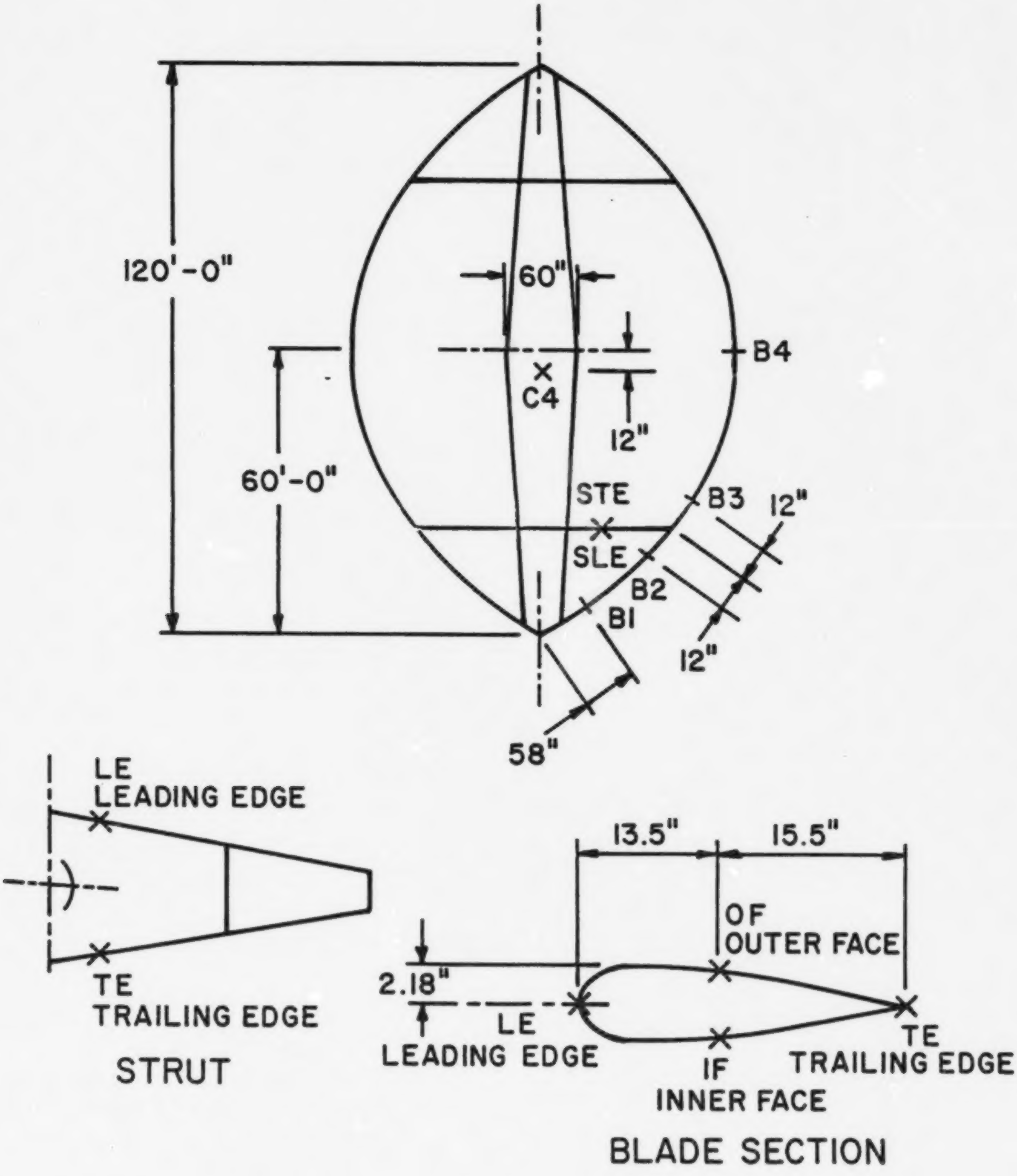
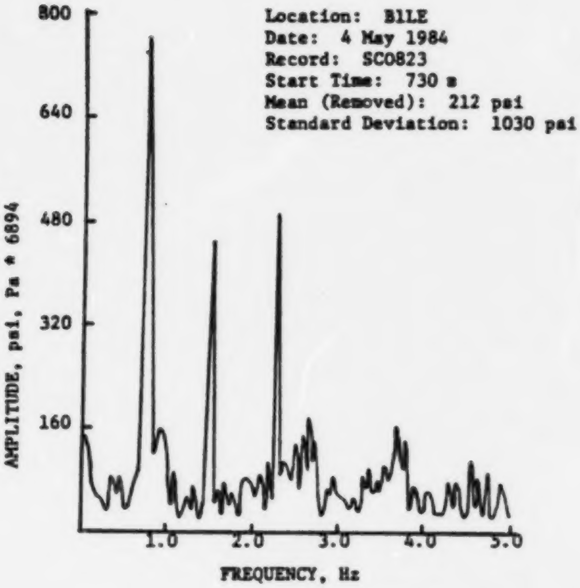
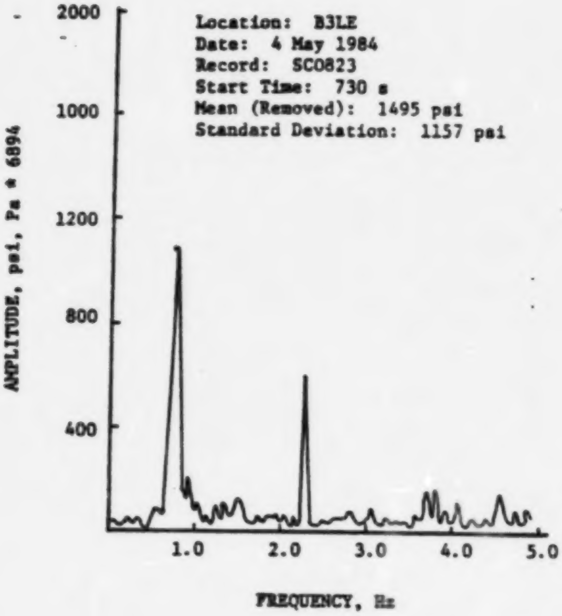

120'-0"
60"
B4
C4
12"
60'-0"
STE
B3
12"
SLE
B2
B1
12"
58"
LE
LEADING EDGE
TE
TRAILING EDGE
STRUT
13.5"
15.5"
OF
OUTER FACE
2.18"
LE
LEADING EDGE
IF
INNER FACE
TE
TRAILING EDGE
BLADE SECTION

Figure: 5

Strain Gauge Locations



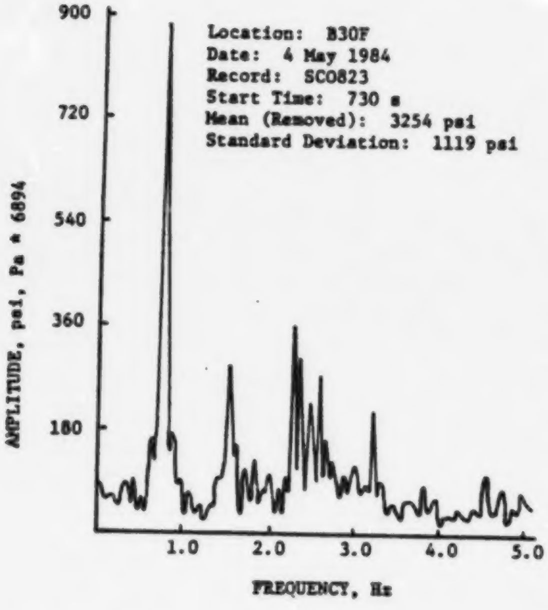
Typical Spectrum of Stresses
from B1LE



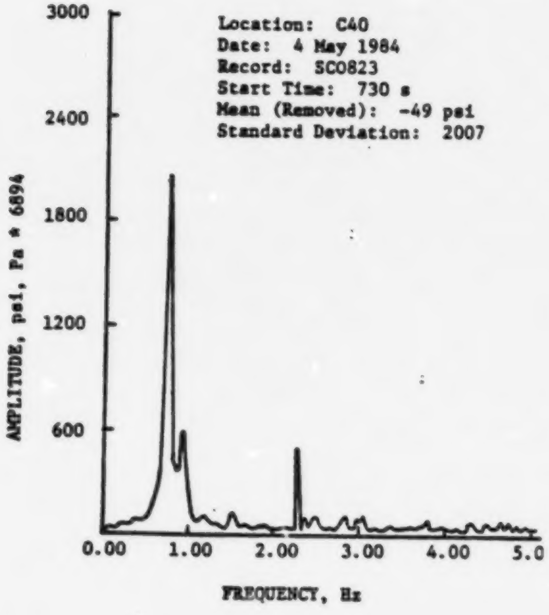
Typical Spectrum of Stresses
from B3LE

Figure: 6

Typical Stress Spectra



Typical Spectrum of Stresses from
B30F



Typical Spectrum of Stresses
from C40

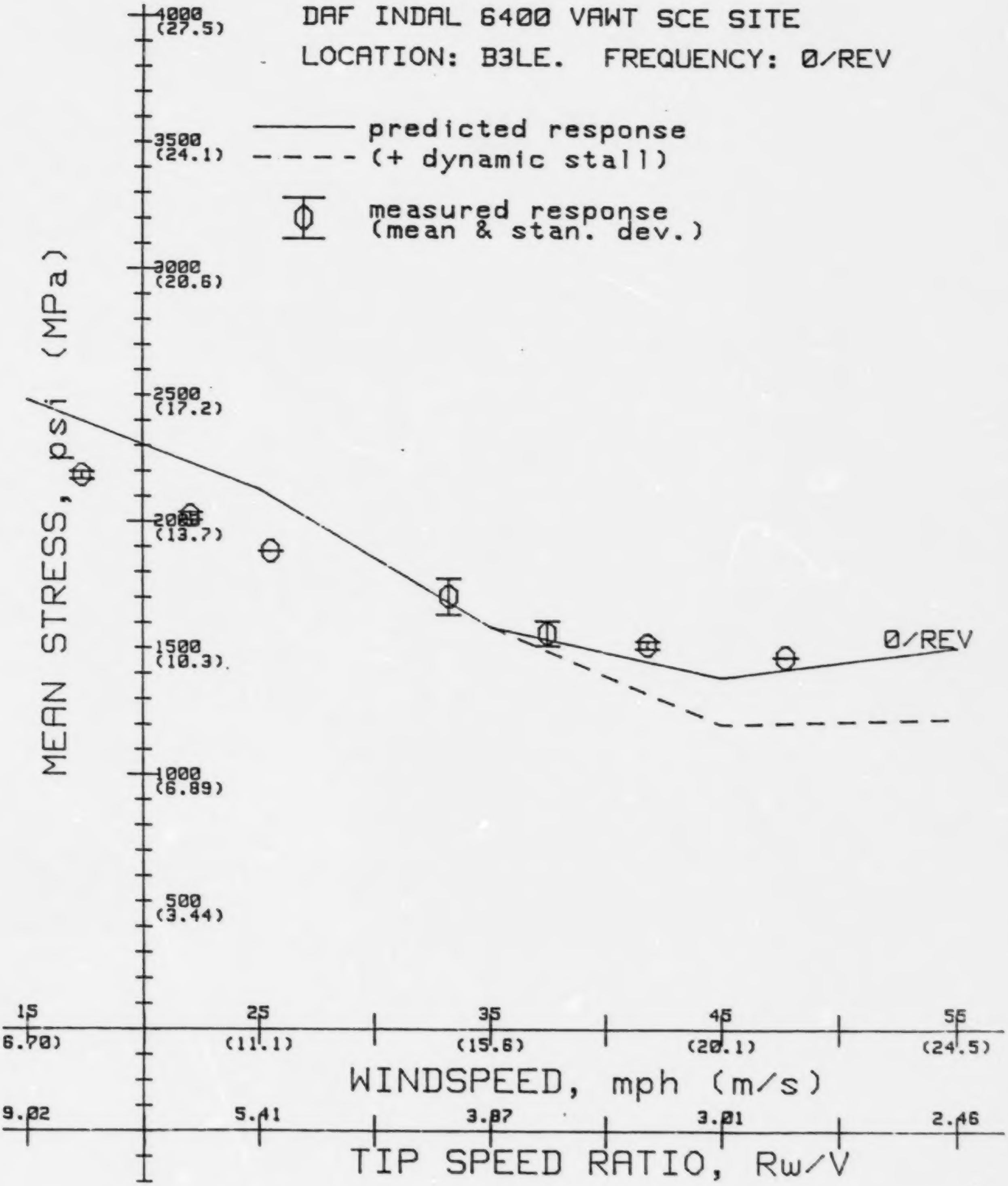

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B3LE. FREQUENCY: 0/REV
predicted response
(+ dynamic stall)
measured response (mean & stan. dev.)
MEAN STRESS, psi (MPa)
4000 (27.5)
3500 (24.1)
3000 (20.6)
2500 (17.2)
2000 (13.7)
1500 (10.3)
1000 (6.89)
500 (3.44)
0/REV
15 (6.70)
25 (11.1)
35 (15.6)
45 (20.1)
55 (24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rw/V

Figure: 7

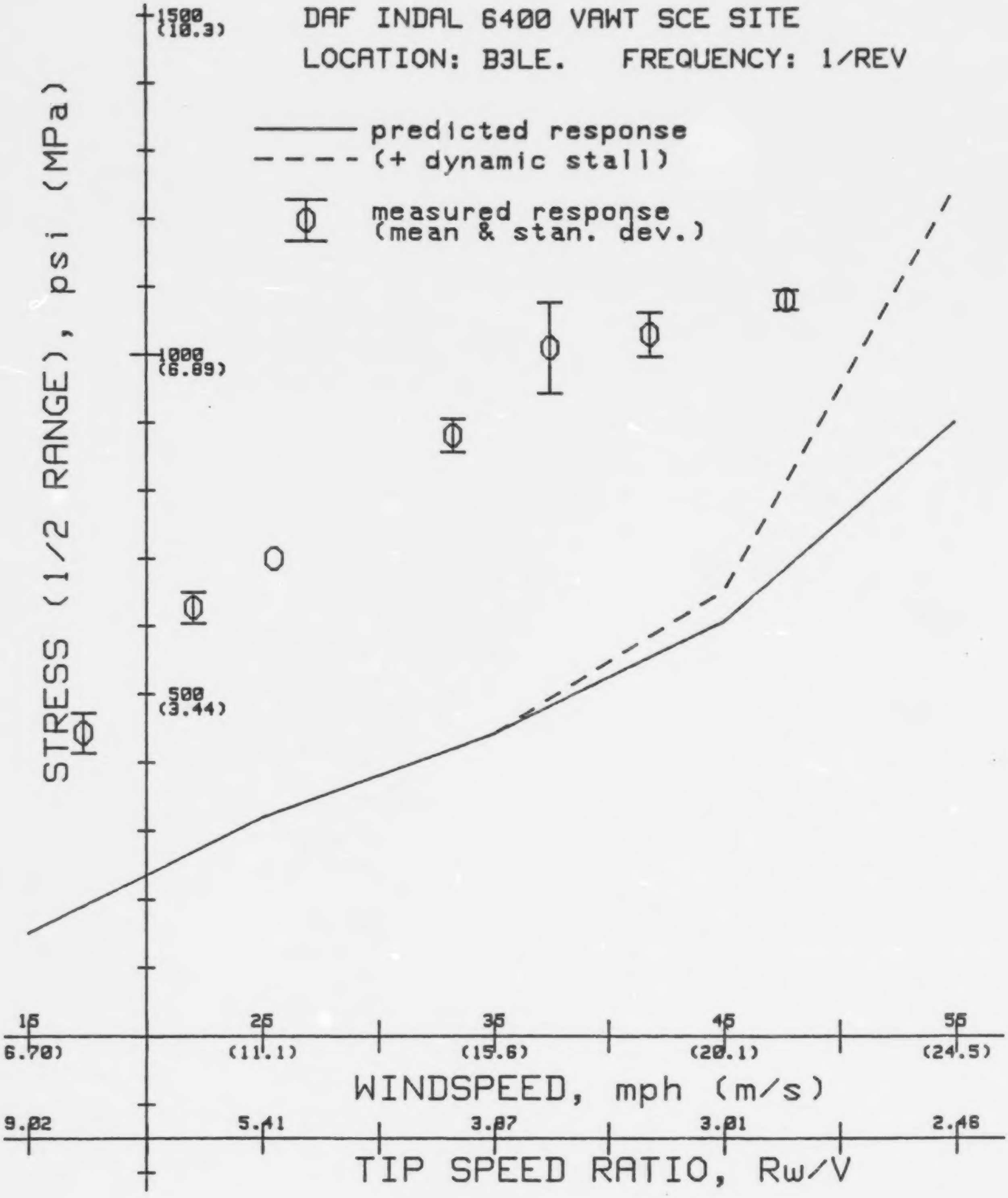

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B3LE. FREQUENCY: 1/REV
predicted response
(+ dynamic stall)
measured response
(mean & stan. dev.)
STRESS (1/2 RANGE), psi (MPa)
1500
(10.3)
1000
(6.89)
500
(3.44)
15
25
35
45
55
6.70)
(11.1)
(15.6)
(20.1)
(24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rw/V

Figure: 8

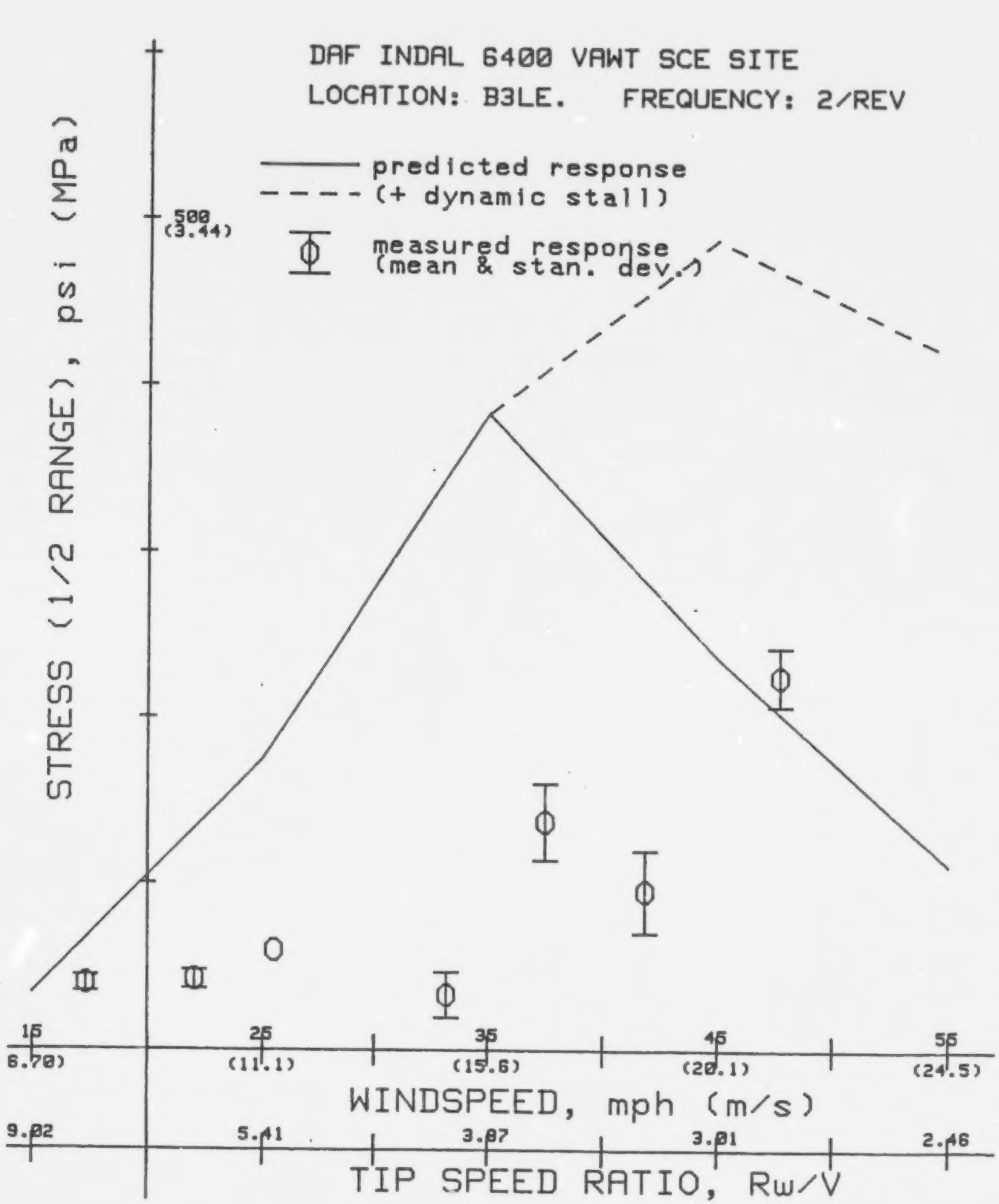

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B3LE. FREQUENCY: 2/REV
predicted response
(+ dynamic stall)
measured response
(mean & stan. dev.)
STRESS (1/2 RANGE), psi (MPa)
500
(3.44)
15
6.70)
25
(11.1)
35
(15.6)
45
(20.1)
55
(24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rω/V

Figure: 9

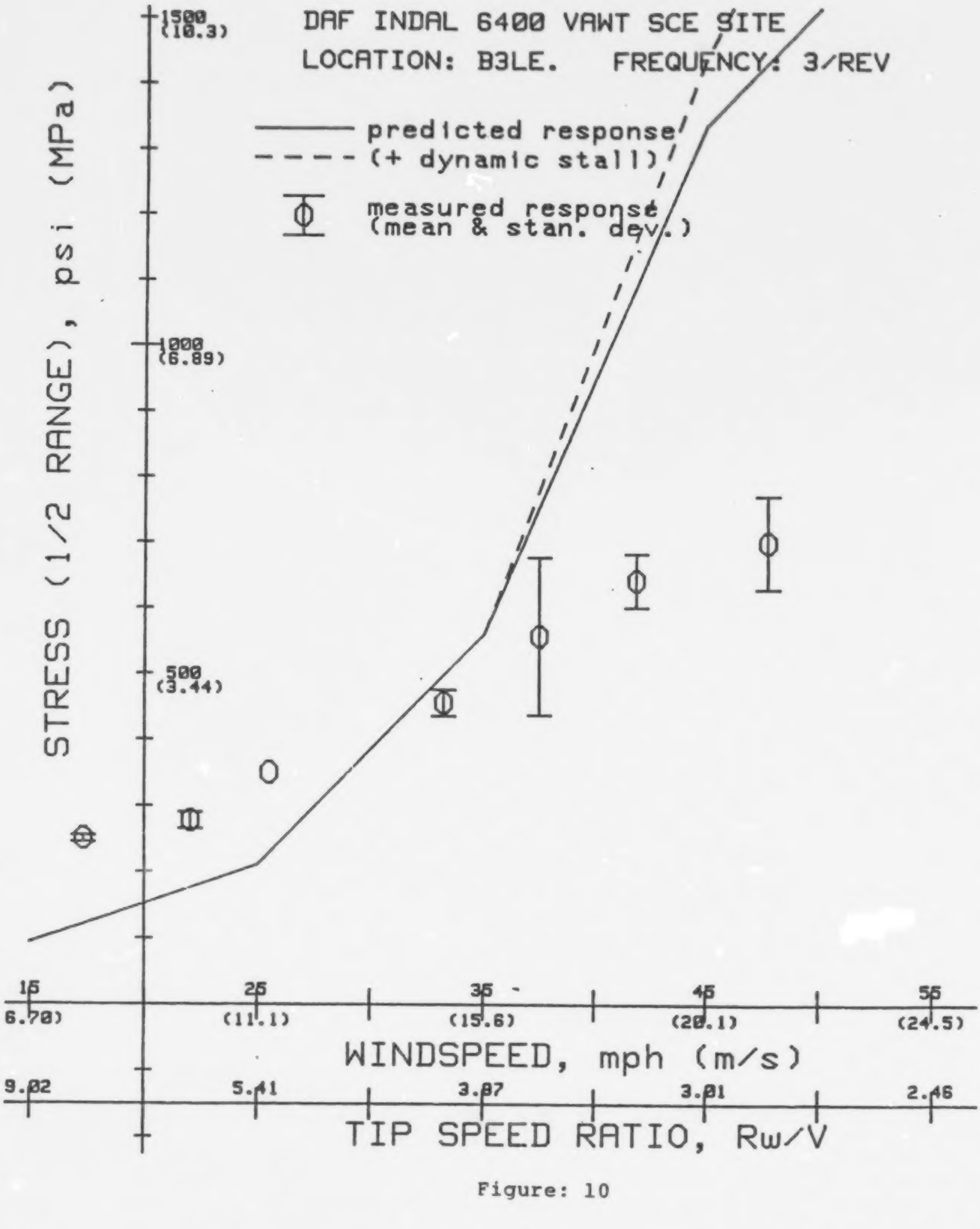

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B3LE. FREQUENCY: 3/REV
predicted response
(+ dynamic stall)
measured response (mean & stan. dev.)
STRESS (1/2 RANGE), psi (MPa)
1500 (10.3)
1000 (6.89)
500 (3.44)
15 (6.70)
25 (11.1)
35 (15.6)
45 (20.1)
55 (24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rw/V

Figure: 10

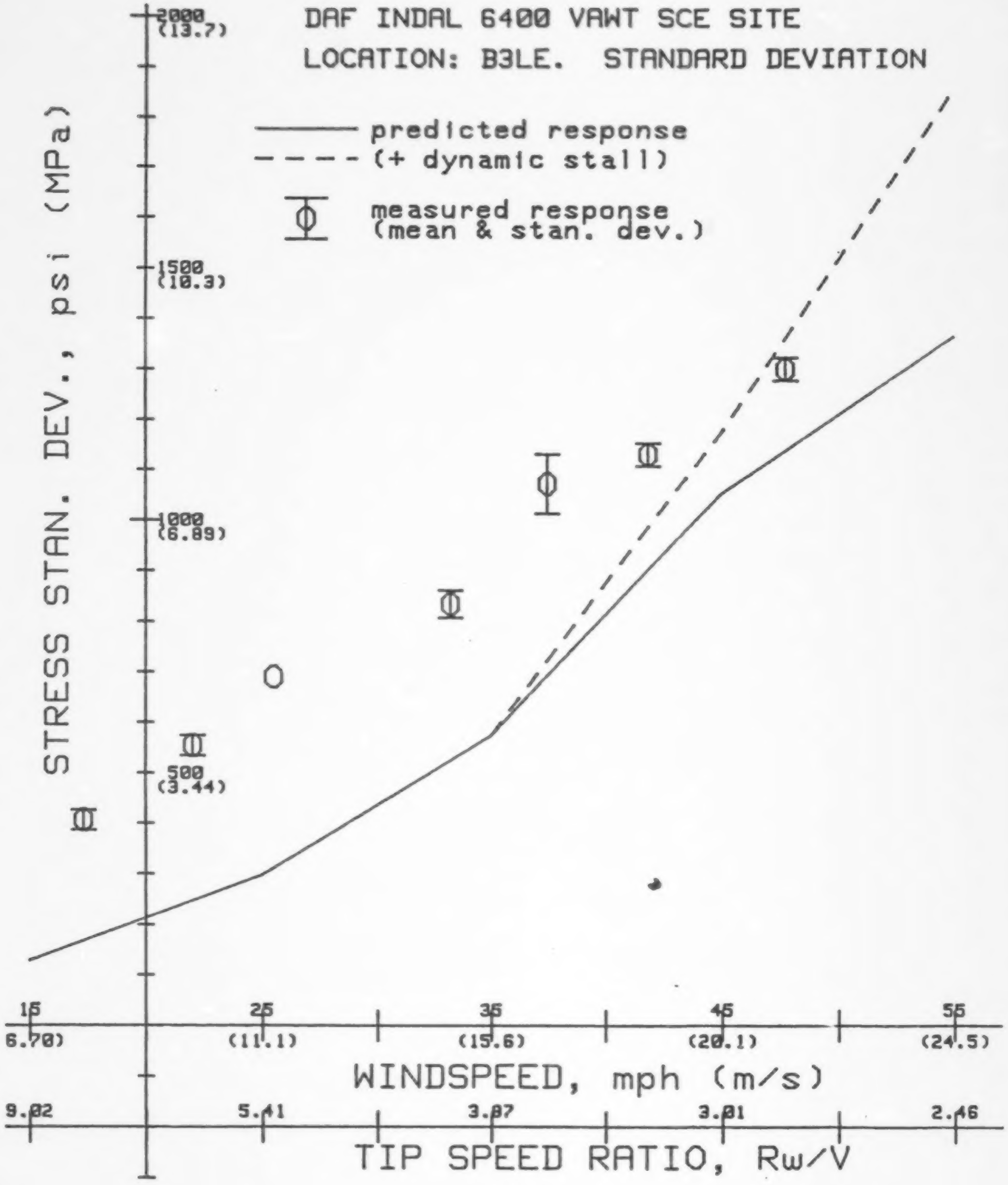

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B3LE. STANDARD DEVIATION
predicted response
(+ dynamic stall)
measured response
(mean & stan. dev.)
STRESS STAN. DEV., psi (MPa)
2000
(13.7)
1500
(10.3)
1000
(6.89)
500
(3.44)
15
(6.70)
25
(11.1)
35
(15.6)
45
(20.1)
55
(24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rω/V

Figure: 11

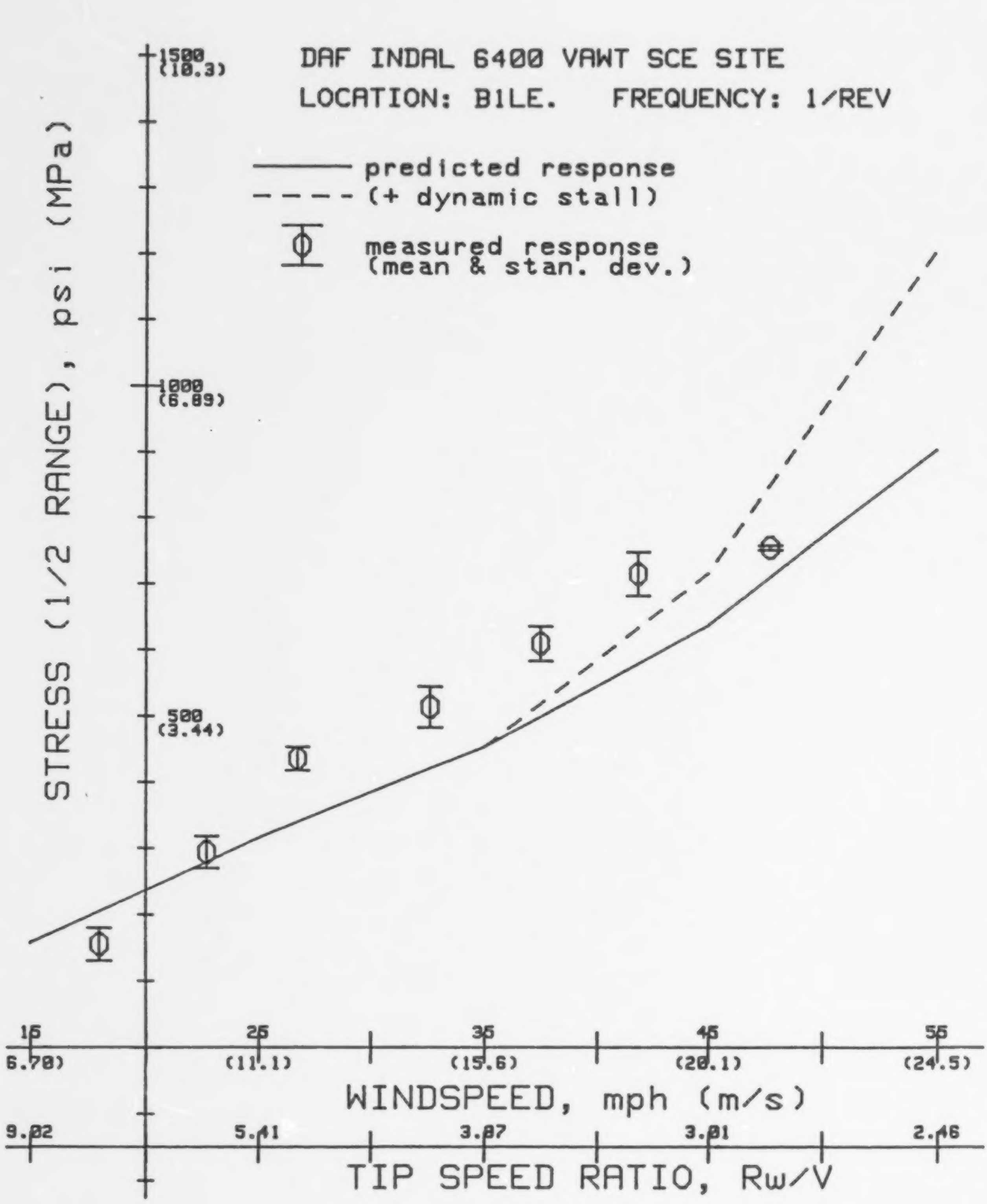

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B1LE. FREQUENCY: 1/REV
predicted response
(+ dynamic stall)
measured response
(mean & stan. dev.)
STRESS (1/2 RANGE), psi (MPa)
1500 (10.3)
1000 (6.89)
500 (3.44)
15
(6.70)
25
(11.1)
35
(15.6)
45
(20.1)
55
(24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rw/V

Figure: 12

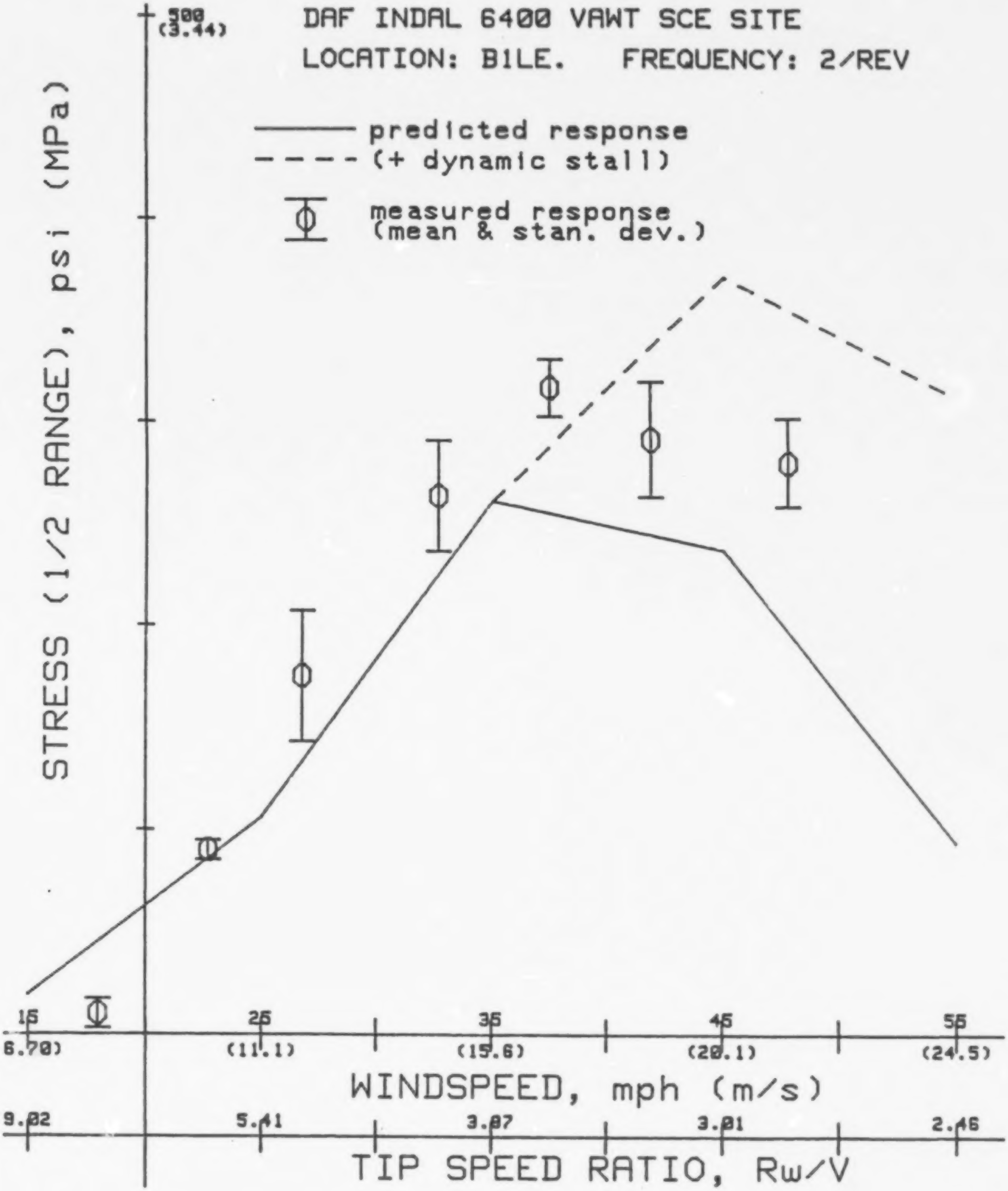

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B1LE. FREQUENCY: 2/REV
predicted response
(+ dynamic stall)
measured response
(mean & stan. dev.)
500
(3.44)
STRESS (1/2 RANGE), psi (MPa)
15
(6.70)
25
(11.1)
35
(15.6)
45
(20.1)
55
(24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rω/V

Figure: 13

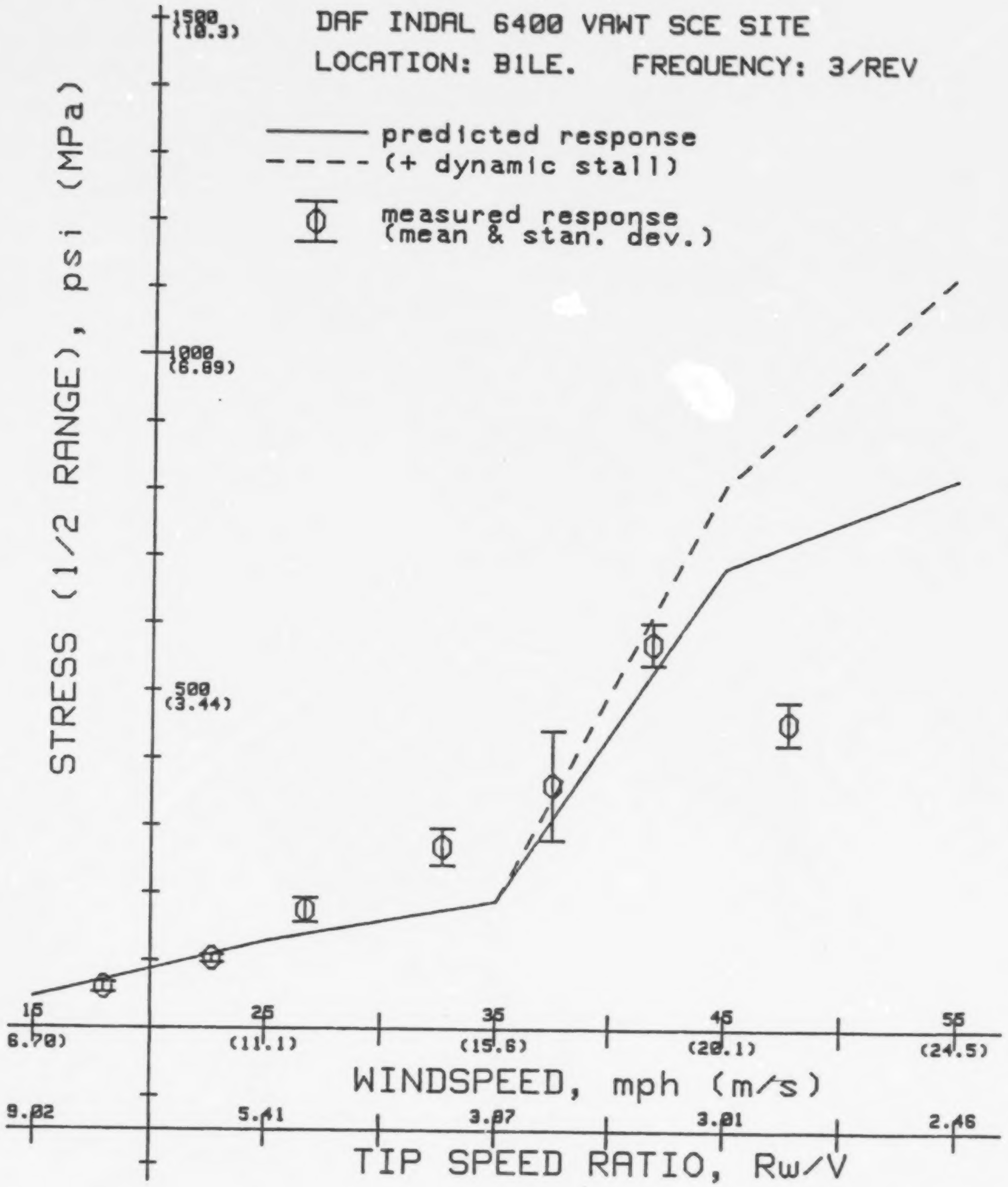

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B1LE.   FREQUENCY: 3/REV
predicted response
(+ dynamic stall)
measured response (mean & stan. dev.)
STRESS (1/2 RANGE), psi (MPa)
1500 (10.3)
1000 (6.89)
500 (3.44)
15 (6.70)
25 (11.1)
35 (15.6)
45 (20.1)
55 (24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rw/V

Figure: 14

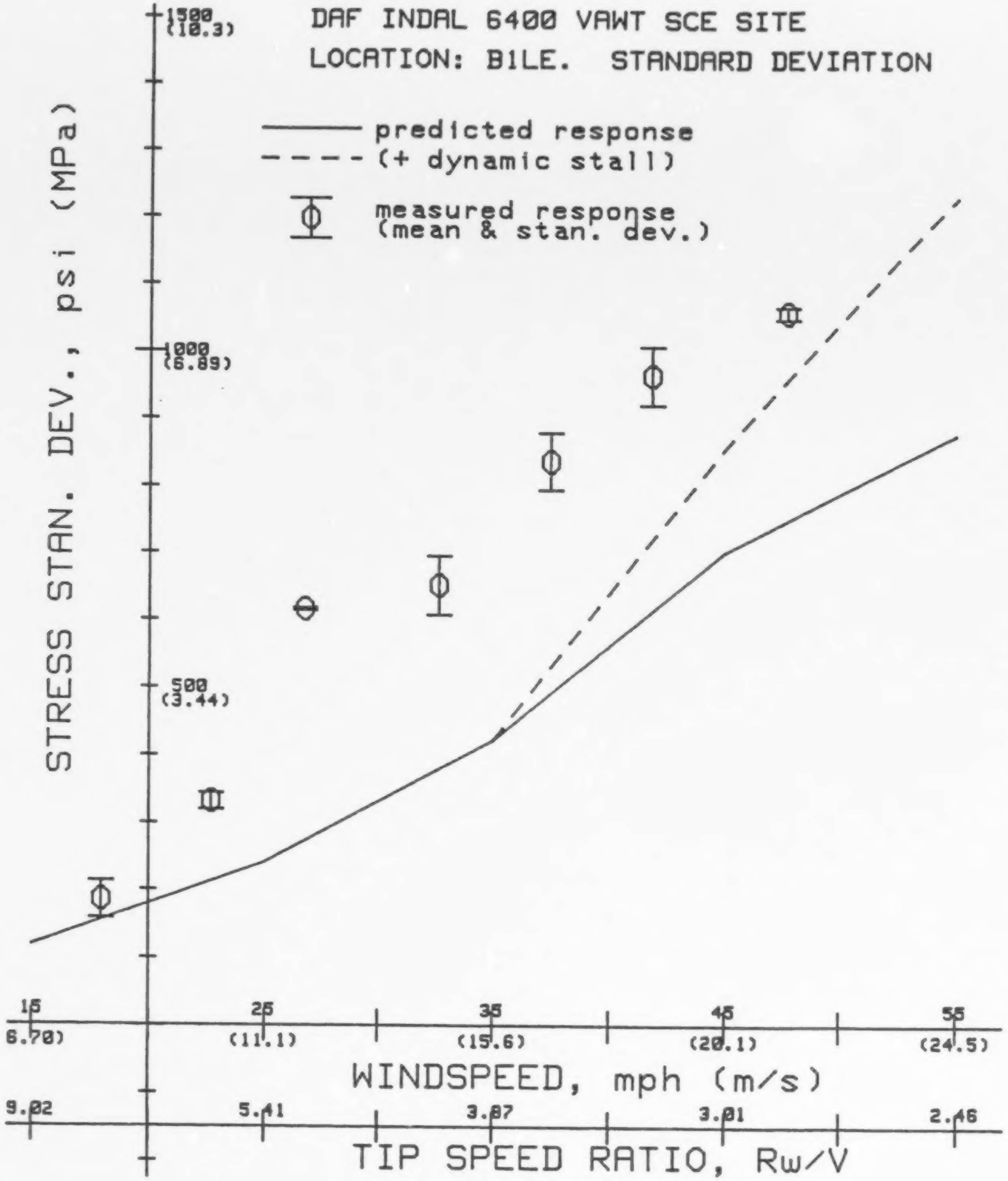
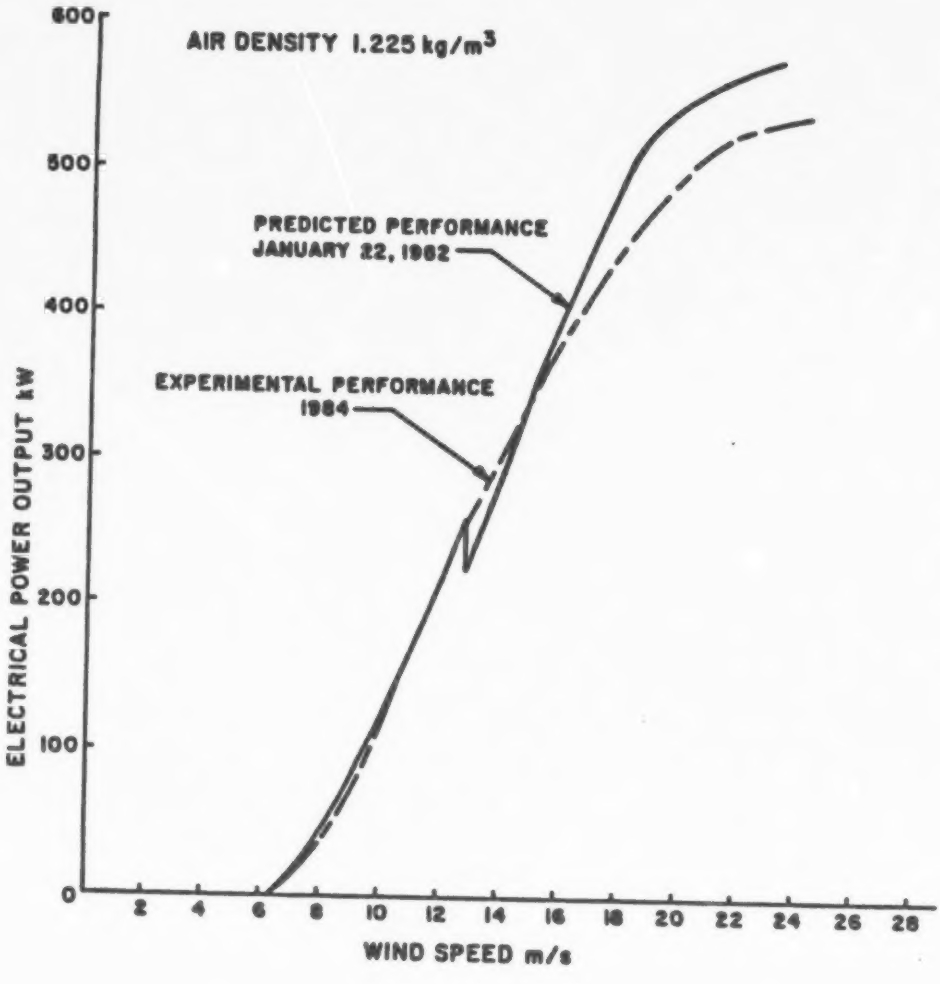

DAF INDAL 6400 VAWT SCE SITE
LOCATION: B1LE. STANDARD DEVIATION
predicted response
(+ dynamic stall)
measured response
(mean & stan. dev.)
STRESS STAN. DEV., psi (MPa)
1500
(10.3)
1000
(6.89)
500
(3.44)
15
(6.70)
25
(11.1)
35
(15.6)
45
(20.1)
55
(24.5)
WINDSPEED, mph (m/s)
9.02
5.41
3.87
3.01
2.46
TIP SPEED RATIO, Rw/V

Figure: 15



DAF INDAL LTD SERIES 6400
MODEL 500kW VAWT PERFORMANCE

Figure: 16

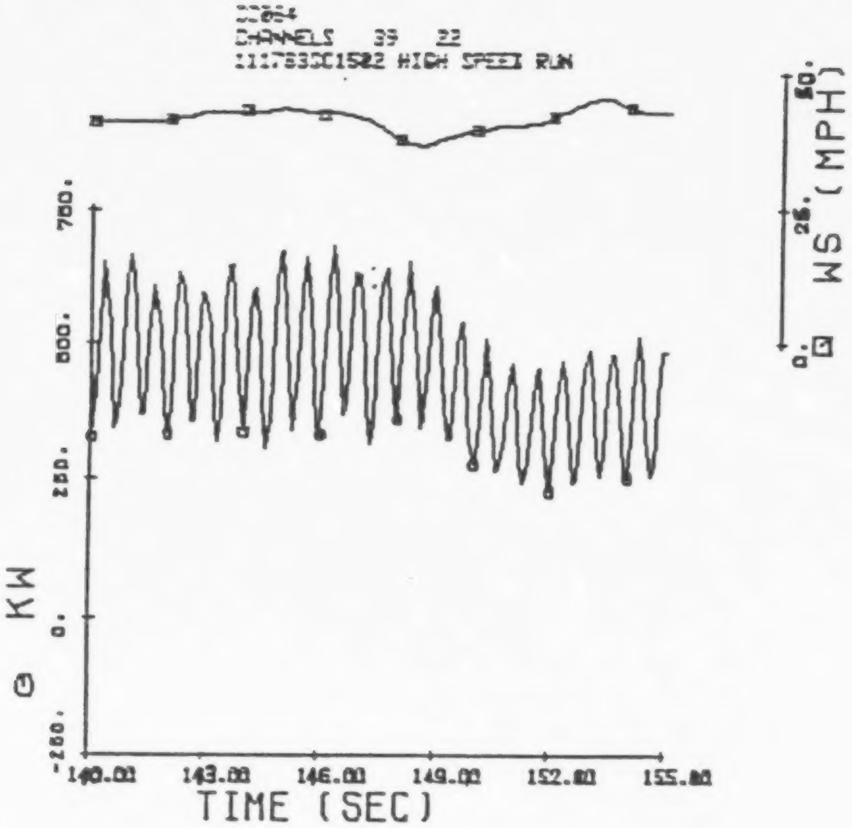


Figure: 17

Record of Power Output

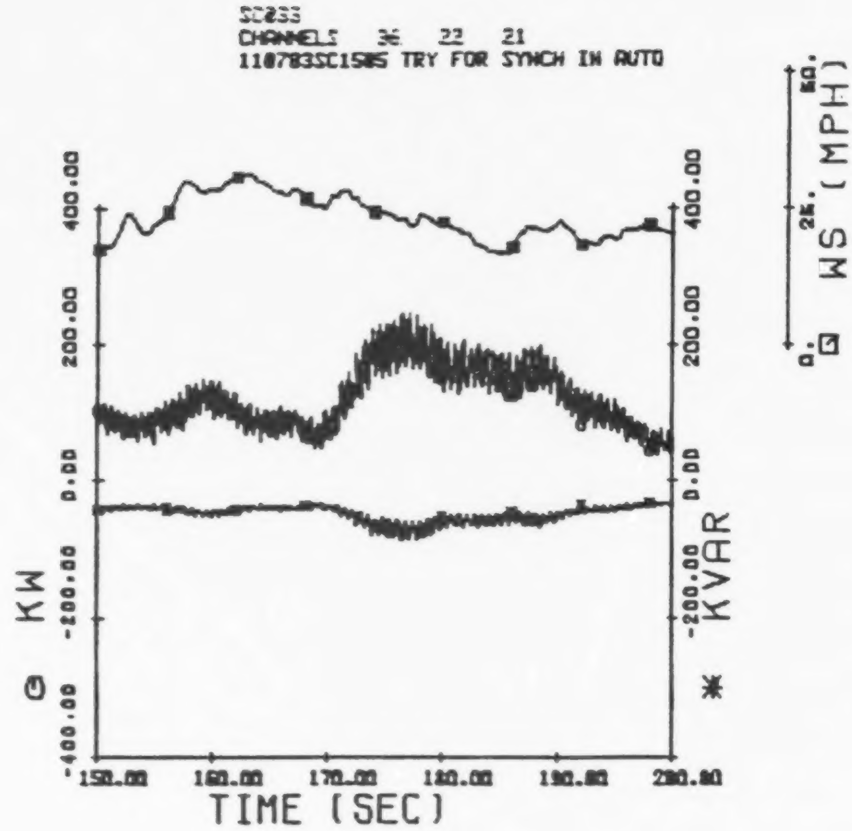


Figure: 18

Record of Real and Reactive Power Output

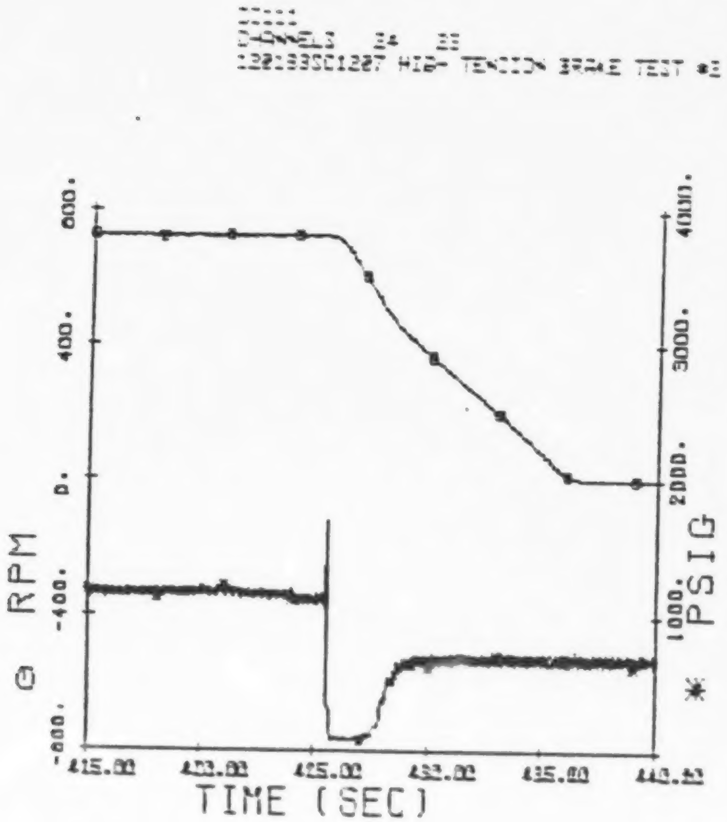


Figure: 19

Record of VAWT Braking

DYNAMOGENESIS SYMPOSIUM DECEMBER 1984

Operating experience with a 300KW aerogenerator in the Orkney Islands

Duncan Hume HOWDEN GROUP CANADA LTD

SUMMARY

Howden installed a 300 Kw aerogenerator at Burgar Hill in the Orkney Islands (United Kingdon) on the 20th October, 1983. This synchronous machine supplies power to The North of Scotland Electricity Board grid and to present, has generated a total of 456 Mw-hours while being on-line for 3,658 hours, giving an average power output of 124 Kw.

A capacity factor of 0.17 has been achieved over the period and during this time design problems have been identified and corrected while strain gauge and other testing has been ongoing. The grid in the Orkneys is unreliable, going down as many as five times in one night. However, the aerogenerator has had no negative impacts on the grid and is able to come on and off line without the local residents noticing. The wind has blown at 100 miles per hour (45 m/s) and the machine, with its epoxy laminate blades, has been unaffected by icing conditions. The utility has already assumed responsibility for regular maintenance.

Design development of this machine has been ongoing with induction generators and longer blades being incorporated in the HWP 300 for the California wind farm market while a low temperature 60 Kw machine, suitable for remote unattended operation in the Canadian North, should soon be in production.

INTRODUCTION

The HWP 300 is a 300 Kw machine which was designed for stand alone operation in remote sites by James Howden & Company, Engineers of Glasgow, Scotland.

The unit has been erected in the Orkney Islands, off the northern tip of Scotland, and is a prototype. Operating experience is being used to develop other machines of different nominal rated power, and machines for other applications such as windfarming.

A paper was presented last year at this Conference by Alan Brown of James Howden & Company entitled '300 Kw HAWT in the Orkneys' which described the basic design concepts and gave a detailed description of the machine.

GENERAL DESCRIPTION

Rotor

The HWP 300 has a three-bladed, fixed-pitch upwind rotor. The rotor diameter is 22 metres and the running speed is 45 rpm. A three-bladed rotor provides smooth power output, balanced gyroscopic forces and good start up characteristics. The upwind rotor location produces low blade, flapwise stresses induced by the tower aerodynamic shadow, this significantly reduces this potential rotor fatigue condition.

The rotor blades are of a wood/epoxy laminate construction. The aerofoil section used is NASA GA (W)-1, which is a high performance aerofoil for low speed applications. This aerofoil has superior performance throughout the Reynolds range. The truncated trailing edge has the effect of postponing stall and enables a simple, strong, structural joint to the made.

The blades have been designed for a twenty-five year fatigue life operating in extreme environments. The strength member of the main blade is a 'D' spar comprising vacuum-formed khaya/epoxy laminate sides, a khaya veneer and epoxy leading edge and twin spars of 18 mm. birch plywood. The trailing edge is of a very much lighter sandwich construction with the 4 mm. birch plywood skin which continues from near the leading edge, forming one side of the sandwich, and 3 mm. gaboon plywood forming the other; the space in between is filled with 15 mm. PVC structural foam.

The main blade root to hub fixing comprises 20 high-tensile step-tapered studs set in a carbon fibre/epoxy grout in step-tapered holes in the khaya/epoxy laminate. The step tapering allows a progressive transition between the flexible wooden blades and the inflexible steel hub. The load is taken in sheer both through the adhesive bond and through the mechanical keying of threads. The epoxy/wood interface relies on the adhesive bond alone, which tests have shown is stronger than the wood itself. The tip mechanism is bolted to a steel plate held on by ten step-tapered studs in a similar arrangement to the root studs but on a smaller scale.

The design wind speed for the blade is 67 m/s (150 mph). This is the wind speed at which the stress on any part of the blade will not exceed the predetermined design limit for that part of the blade. The survival wind speed for the rotor is calculated at 94 m/s. (210 mph).

Each blade incorporates a fail-safe, variable pitch tip section. The tips are held hydraulically in the run position (fail safe) for normal operation and they are turned 60 degrees to the plane of rotation of the rotor by spring and centrifugal action in the event of a system failure, or for a normal shutdown sequence. The tips are also used for speed control during synchronizing and for power limiting.

Hydraulic fluid is passed to the tips via a hydraulic pipe which is mounted in a plastic tube that is built into the main blade. The plastic tube allows the pipe to be replaced if necessary and it will contain any hydraulic leakage should a failure occur. The tip mechanism is completely contained within the tip; no mechanical components or items requiring maintenance are built into the main blade. The tip mechanism is grease-lubricated and has a lip seal to exclude dust and moisture.

The exposed surfaces of the tip and main blade are skinned with a woven glass cloth which increases the thickness of the final layer of epoxy and adds to abrasion resistance. White polyurethane paint covers this layer and, being a close chemical neighbour to the epoxy, bonds very well. The paint forms a barrier to ultraviolet light which would otherwise degrade the epoxy.

The leading edge of the blade has a 100 mm. wide polyurethane anti-abrasion tape and the tip and end sections are completely covered by an expanded and flattened aluminum mesh that is attached to down conductors in the leading and trailing edges of the blade to provide protection against lightening strikes.

Nacelle Equipment

The hub is a spheroidal, graphite cast iron unit that is subjected to chemical, mechanical and ultrasonic examination; it is attached to the low speed shaft using a taper fit. The hub can easily be fitted and removed using a small hand pump and hydraulic nut. The interference between the hub and shaft is such that several times the full load torque can be transmitted without the use of keys. The absence of a key reduces stress concentrations in this highly stressed area.

The brake disc is bolted to an integral forged hub on the low speed shaft. The use of a low speed shaft brake reduces the number of components between the brake and the rotor and this improves the safety of the system and removes the braking forces from the gearbox and shaft couplings. The brakes are fail safe, the springs being held open by the hydraulic system; two callipers are used, balancing the braking forces without loading the shaft bearings. The brake system is fully capable of stopping the rotor from an overspeed condition without the use of the blade tips. Brake pad wear sensors are used to prevent the aerogenerator from operating with excess pad wear. A mechanical shaft lock is provided to positively lock the shaft during maintenance.

The gearbox is a standard, proprietary three-stage speed increasing drive. This unit has been chosen for its known reliability and ease of maintenance. Splash lubrication is used with a mechanically driven cooling fan mounted on an extension to an intermediate shaft. A sensor is mounted in the sump to shut down the generator in the event of high temperatures.

The generator is a standard, off-the-shelf, four pole, two bearing synchronous machine delivering alternating current. The generator's output is transmitted via twistable cables. The generator is designed with a self-contained cooling system which circulates coolant air through the machine. Ambient air is drawn into the machine through louvred openings at the non-drive end of the machine. The warm air is exhausted to the nacelle interior through the drive end. Thermocouples are incorporated in the stator windings for over-temperature protection.

The generator is fully protected for use in a marine environment and is fitted with anti-condensation heaters.

The nacelle is joined to the tower at a large diameter slewing ring. This yawing system consists of three direct drive, low speed axial position motors that are associated with spring-applied, hydraulically released calipers. The brakes are used to damp out oscillating forces when yawing and to lock the nacelle in the desired operating position.

Yawing is normally done while the machine is generating power. However, should a yaw movement result in the twistable cables, (that run down through the tower from the generator to the control panel) being twisted more than three full turns, the aerogenerator will automatically come off the grid and bring the rotor to a stop. It will then yaw until the cables are untwisted. This is not an event that is expected to occur frequently and has not yet occurred on the Orkney machine. Full access can be gained to all the yaw system components from the tower interior. There is a mechanical lock for the yaw system that can be applied during maintenance.

Tower

The tower for the HWP 300 is a hollow cylinder 1.82 metre outside diameter. The base which houses the control and instrumentation equipment is a cone with a height of 5 metres and a base diameter of 4 metres. The tower base incorporates the access door and the aerogenerator erection hinge. The tower is built up from three sections for ease of transport and erection. Each section has internal flanges for connection to its neighbour and longitudinal stiffeners welded to the inside. Access from the control room in the tower base to the nacelle is by internal ladders with intermediate platforms at three levels.

A folding platform is provided in the tower mid-section for access to the blade tip mechanisms. The height to the rotor centreline is 22 metres.

CONTROL AND PROTECTION SYSTEM

The control and protection system of the HWP 300 is designed to provide safe operation of the machine in unattended status and is in the form of three different panels housed in the base of the tower, these are: switchgear panel, instrumentation panel and computer panel.

The panels are designed to provide simple installation of the Control Room in the remotest of sites. The panels are interconnected using a prewired plug and socket system. The cabling and conduit system has been designed to allow maintenance personnel to quickly trace and identify cables as required. This system also allows the panels to be connected and tested prior to shipment to site.

The definitive method of isolating the aerogenerator from the grid is a circuit breaker which must be hand-closed. The circuit breaker is therefore only tripped by the control system during fault conditions. A proprietary 'switchgear tripping battery' has been provided to ensure that, should the circuit breaker receive a trip signal from the computer or any of the hardwired protective devices, it will be capable of tripping. The normal manner of connecting or disconnecting the generator to or from the grid is by means of the contactor which is normally opened and closed automatically by the control system but may be controlled manually if the HWP 300 control system is set for manual operation.

The switchgear panel contains two front door mounted polyphase kilowatt hour meters which measure kilowatt hours 'in' and kilowatt hours 'out' respectively. These are proprietary industrial type meters which are calibrated by the manufacturer. If required, the meters can be calibrated complete with current transformers by an independent testing agency.

The instrumentation panel contains the transducers that convert the power level signals, relating to the generator status, to a level acceptable to the computer. In addition, the panel houses the hardwired relay system which provides a secondary protection scheme for the machine.

The relay system is designed so that any individual relay can trip the main circuit breaker via the tripping battery should the computer fail to react in the correct manner to any fault condition.

The computer panel contains the computer and its associated input and output modules. The computer is of a proven design with many years of industrial plant use. The machine is monitored and protected by a number of software routines contained within the computer. These routines monitor the health of the HWP 300 independent of whether or not it is generating electrical power. If a fault condition is detected the nature of the fault is displayed on the VDU and a hard copy provided via the printer.

The protection strategy is such that any internal fault of the HWP 300 will cause the computer to trip the main circuit breaker, thus isolating the machine from the grid. An operator must go to the installation and rectify the fault before manually resetting the circuit breaker .

The language utilised by the computer for control purposes is ladder logic. This language is particularly suitable for maintenance and fault finding as it is readily understood by plant maintenance personnel.

TRANSPORT AND ERECTION

The aerogenerator has been designed to be erected in remote locations without the use of large cranes. The tower, nacelle bedplate, nacelle cover and rotor are assembled at ground level with the tower lying horizontally. The tower is pivoted at the base and raised to the vertical position by a come along system operating with an 'A' frame.

Once the machine is in the vertical position the electric hoist that is built into the nacelle is used for lifting the generator, gearbox and other equipment into the machine from ground level. The hoist is also used during maintenance.

The Orkney machine was site assembled and erected in a total time of two weeks, using a crew of eight. The lift into the final vertical position, using a diesel powered 10 ton winch, took twenty five minutes to complete and was carried out in a 15 m/s (35 mph) wind.

COMMISSIONING

The drive train components are all standard proprietary items, and commissioning followed the normal practice of line out and lubrication. The machine control panel which incorporates the hydraulic powerpack is provided with a set of manual controls which function entirely independently of the control computer. This allowed the various systems, yaw motors and brakes, main shaft brakes and blade tips to be tested at an early stage. The first mechanical runs were also carried out using the manual controls in the nacelle.

The hardwired, over-speed trip was commissioned before any operation of the rotor was attempted. The over-speed trip functions in a similar manner to the protection relays and is completely independent of software protection in the control computer. At an early stage in the design, it had been decided to provide full hardware backup to the computer in terms of protection relays, over/under voltage, over/under frequency, overcurrent, reverse power, negative phase sequence, and earth fault. These relays enabled the correct functioning of the protection system to be verified by the North of Scotland Hydro Electric Board engineers using standard injection tests leaving much more freedom to commission the software since grid safety had been assured.

A number of delays occurred during commissioning, due to wiring faults in the control panels and also to damage in the controller input/output modules. It is thought that the damage was caused by an earth fault in the remote indication wiring. The simple modular concept of the controller allowed the damaged modules to be replaced easily once the fault had been identified.

The system was first synchronised to the grid under manual control on October 20th, 1983. The various automatic control routines were introduced in stages, allowing automatic operation to be achieved during November. The machine was put into full unattended status on December 22nd 1983.

OPERATION

The original concept of a simple, reliable wind turbine which would operate automatically and unattended has been satisfied by the installation at Burgar Hill. As was expected, there have been a number of operational problems and these have resulted in modifications to this machine, in the light of this experience. The new design concepts have been incorporated into our other machines that are presently being manufactured or designed.

This is an operational summary to the 20 November 1984:

Total hours on-line	3,658
Total power generated	455,650
Maximum weekly hours on-line	143
Maximum weekly availability	100 %
Maximum weekly average power	243 Kw (83 hours)
Average power to date	124 kwH
Availability to date	78.4 %
Capacity factor	0.173

During this time, various different philosophies have governed the machine's operation. Initially the requirement was to get some operating hours on the machine so that the inevitable teething problems would manifest themselves. By May 1984 the emphases had shifted to testing and a DEC LSI 11 microcomputer was installed. This system collects the data, analyses it and then stores it automatically. The logger monitors ten strain gauge channels at 32 Hz and stores the processed data in the form of rainflow matrices on three megabyte tape cartridges. Other signals, including wind speed, wind direction, power output and ambient conditions are recorded. The logger is accessed daily from our Glasgow office via a modem link.

The data being recorded is being used to verify or modify design criteria thus allowing improved design for future machines.

PROBLEMS ENCOUNTERED

Freewheel Coupling

In order to assist with synchronising of the generator to the grid and to prevent the rotor from being motored in low wind speed conditions, it was felt prudent to include a freewheel coupling in the high speed shaft. After approximately twenty hours of operation, the coupling failed due to the very high differential speed across the coupling during the rundown of the generator under normal stopping conditions. The coupling failed in such a way that it would not drive in either direction and was removed and replaced with a solid flange coupling. This has proved to be entirely satisfactory. No problems have been encountered with reverse power trips at low wind speed and the control system has successfully synchronised the generator in winds gusting up to 30 m/s. (70 mph).

Hydraulic Actuators - Blade Tips

It was noticed, after approximately two hundred hours of operation, that hydraulic oil was leaking from the blade tips. The actuator seals were diagnosed as being the source of the leak and these were replaced; the leakage reappeared and it was judged necessary to modify the actuator design. As part of the redesign, additional spigots were used on certain of the components to ensure concentricity and bearings were introduced to reduce the side loadings on the seals. Since the implementation of these modifications the tips have operated satisfactorily for in excess of three thousand hours.

TV Interference

Just when the machine was beginning to run on a continuous basis complaints were received from the local residents about their TV reception. This caused several weeks of shutdowns during the early evenings. As the North of Orkney is a poor reception area and the interference signal was very weak, the problem was simply solved by the installation of signal boosters in the antenna systems,

Cut In and Cut Out

The control system was set to allow two attempts to reach full speed and synchronise the generator before tripping the aerogenerator and reporting a fault situation. After a string of 'failure to synchronise' faults during a low wind period it was discovered that if the machine was starting from cold in low winds, the losses in the gearbox could prevent the rotor from reaching full speed until the oil in the gearbox became warm.

Two changes were made to remedy this condition: firstly, the generator was changed to synthetic oil and secondly, the setting for the cut-in wind speed, which had been determined by the operation of the machine during its commissioning runs as cut-in at 6 m/s. (12 mph) and the cut-out at 4 m/s. (10 mph), was reset to provide a cut in at 7 m/s. (16 mph). In high winds the aerogenerator cut-out is 28 m/s. (63 mph) with the cut-in at 25 m/s. (56 mph). No problems have been encountered with synchronising in high winds and it is normally accomplished in less than one minute.

Grid Fault

The transducer which was installed to monitor power output from the generator, was initially specified as being for a balanced electrical system and it therefore measured a single phase only. The electrical system at Burgar Hill was not balanced and, as the red phase was sometimes as much as 20 volts low, this caused the power performance measurements to be delayed until a replacement transducer was installed.

Over Speed Trip

A recurring over-speed trip was eventually diagnosed as the control system mistaking a grid fault trip for an over-speed trip; grid faults are quite common in the Orkney Islands. This was solved by a software modification that requires the control system to check the grid status immediately an over-speed condition is identified.

Hydraulic Valves

The original hydraulic system consisted completely of spool valves. These valves allow a small leakage under all operating conditions and after six months of operation these valves were all beginning to stick intermittently, causing the blade tips to remain in the run position for several minutes after the control system had sent a shut down command. When the problem was identified, a decision was made to go with seating valves. The new system uses all seated valves which are inherently more tolerant of oil contamination. Also the filtration system has been improved by using a pressure filter in addition to the return line filter while the size of the accumulator has been increased to reduce the duty cycle of the hydraulic pump.

Disk Brake

The silting of the hydraulic system also caused a problem with the disc brake which is 'fail safe' and held off by the hydraulic pressure. The silting caused a reduction in the hydraulic pressure causing the brake to be permanently on - creating overheating and subsequent bonding of the disc. No repetition of this problem is expected after the changeover to seated hydraulic valves.

SUMMING UP

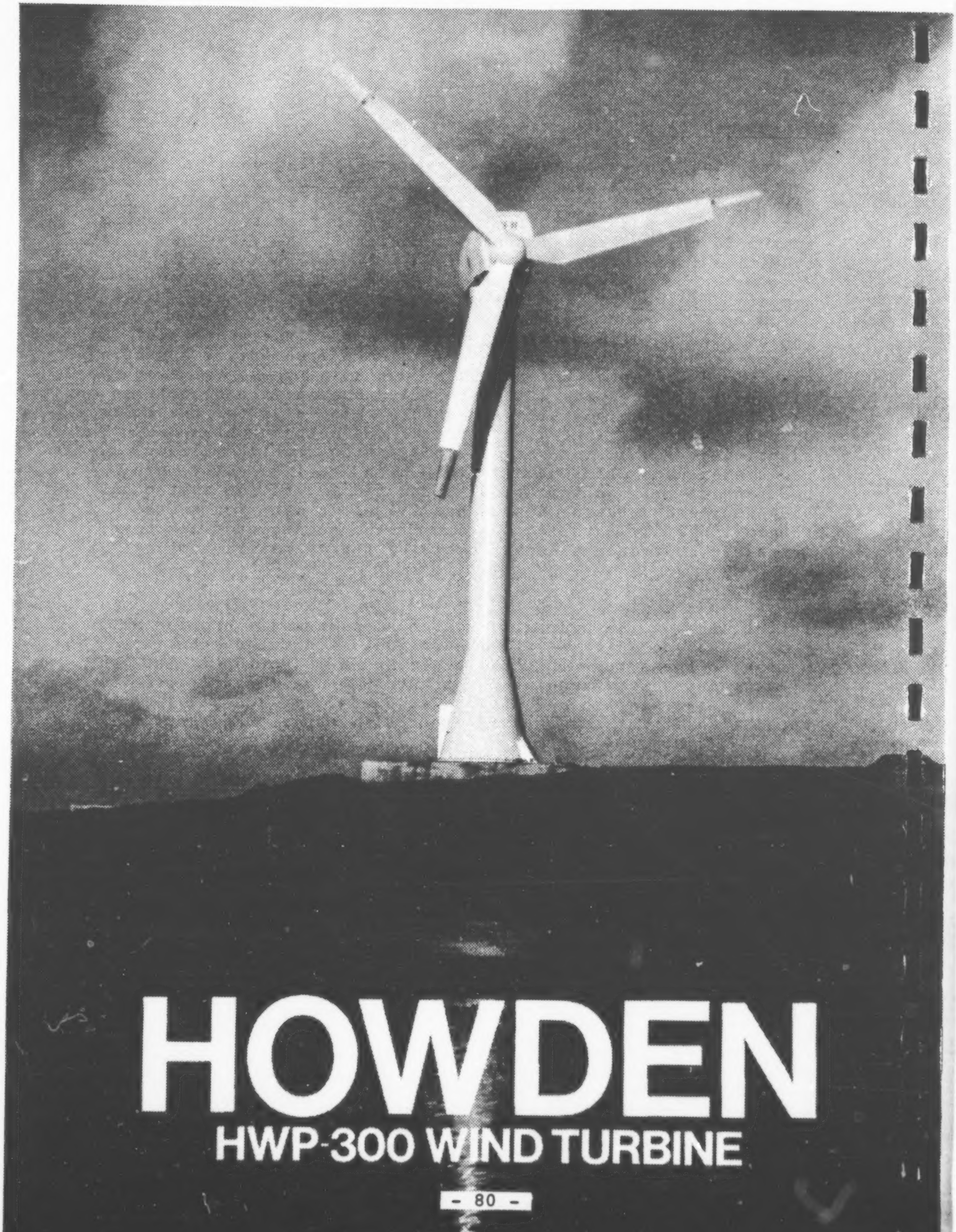
A Howden Wind Farm is currently under construction in California, where ten 330 KW induction wind aerogenerators are to be installed. The first three units are up and are expected to be on line in the near future. The other seven units should be completed this month.

A machine is under construction at the CAL-ED testing site which should be running early in 1985.

A 60 KW induction machine is under construction and will be supplied to the South of Scotland Electricity Board for erection at Pennicuik outside Glasgow. It is expected to be 'on-line' February/March 1985.

Design work is under way to acclimatise the Howden Wind Turbines to the Canadian conditions.

Howden Group Canada
1510 Birchmount Road, Scarborough, Ontario M1P 2G6



HOWDEN

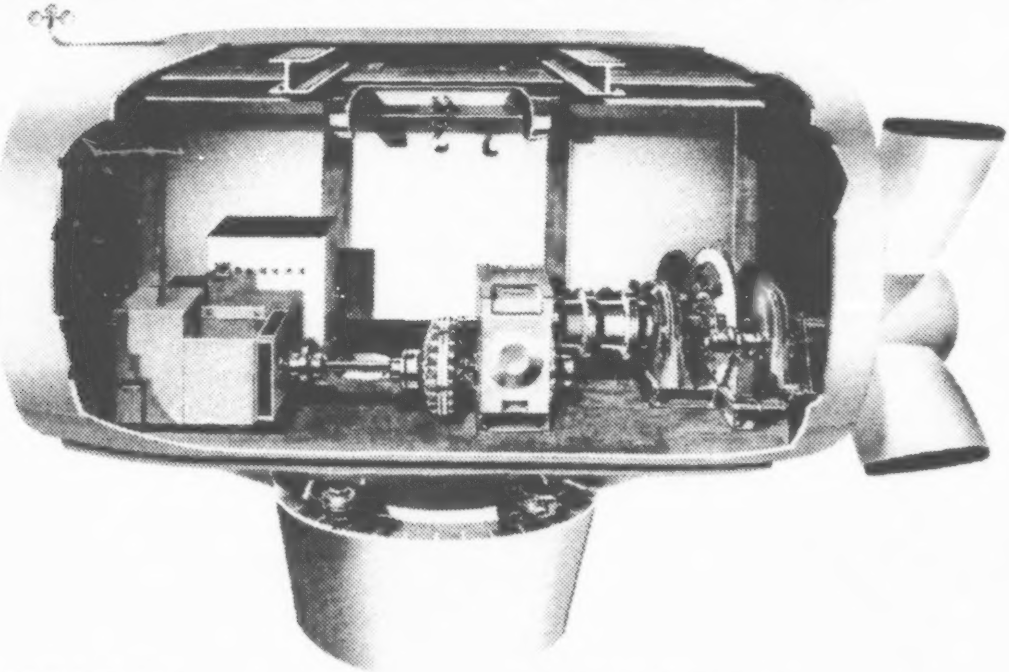
HWP-300 WIND TURBINE

THE HOWDEN PHILOSOPHY

For over 125 years Howden have been in the forefront of innovative design to meet the changing pattern of the world's energy requirements.

With the increasing requirement for alternative energy Howden engineers have developed an economic and reliable 300 kW wind turbine.

This machine is available in two versions; the first is a machine suitable for wind farms or multi-site installation, the second is designed specifically for use in isolated communities or islands and incorporates a number of features to simplify erection and maintenance.

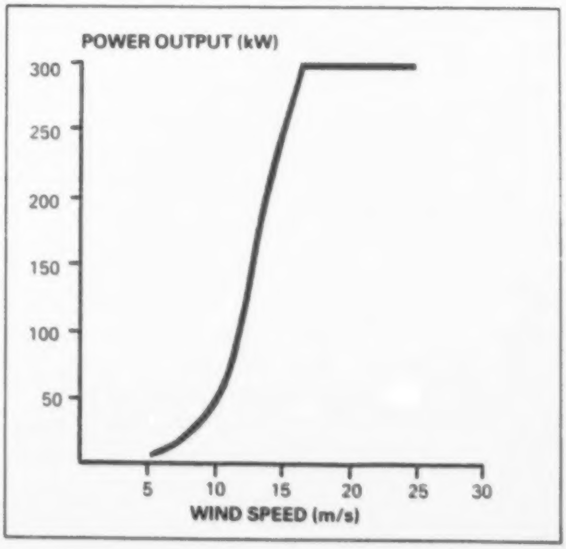


SPECIFICATION

Rotor	
Rotor type	3 bladed upwind
Rotor diameter	22 m
Rotor speed	45 rpm
Blade material	Wood/epoxy composite
Aerodynamic control	Variable pitch tips
Maximum chord	1.4 m
Tip chord	0.8 m
Blade twist	14°
Rotor weight	3000 kg
Transmission	
Gearbox type	3 stage parallel shaft
Gear type	Helical
Gear ratio	34.3:1 or 27.5:1
Generator type	Synchronous or induction
Generator rating	420 kVA
Rated voltage	415 V, 3 Phase
Rated frequency	50 Hz or 60 Hz
Rated speed	1500 rpm or 1800 rpm
Nacelle weight	11000 kg
Tower	
Tower type	Tubular steel
Tower diameter	1.8 m
Base diameter	4 m
Rotor centreline height	22 m
Yaw system	Geared hydraulic motors
Tower weight	15000 kg

PERFORMANCE

Maximum output	300 kW
Rated wind speed	13.5 m/s
Cut-in wind speed	5 m/s
Cut-out wind speed	25 m/s



ROTOR

The three bladed rotor provides smooth power output, balanced gyroscopic forces and good start-up characteristics. Being upwind of the tower, the blades are subject to lower cyclic forces when passing the tower, increasing the fatigue life and contributing to smooth operation.

A fail-safe tip flap on each blade is used for aerodynamic control during start-up, shut-down and for power limiting. This means that the hub and the blade connections are simple and reliable with no moving parts.

The blades are made of a wood and epoxy composite, which has a high strength to weight ratio and good fatigue resistance.

TRANSMISSION SYSTEM

The rotor shaft is mounted in two separate bearings and is connected to the gearbox by a gear type spacer coupling. This arrangement allows work to be carried out on the bearings or gearbox without disturbing the rotor. The low speed shaft disc brakes are spring applied hydraulic released units capable of stopping the rotor from overspeed without the use of the blade tips. The gearbox is a standard unit with oil for the hydraulic tip actuators being supplied via a rotating union through the hollow low speed shaft.

On the high speed shaft between the gearbox and generator are mounted a fluid coupling to provide system damping, and a free wheel clutch to improve the operational strategy.

GENERATOR

A standard 4 pole, brushless, alternating current machine is used. By utilising twistable power cables, all sliding contacts are eliminated from the system, thus ensuring minimum maintenance.

TOWER

A tubular steel tower provides protected access for maintenance and is aesthetically pleasing. The switchgear and control instrumentation are housed in the conical base. Access to the nacelle is by internal ladders. For ease of transportation and handling, the tower is made in sections and bolted together through internal flanges.

MICROPROCESSOR CONTROL

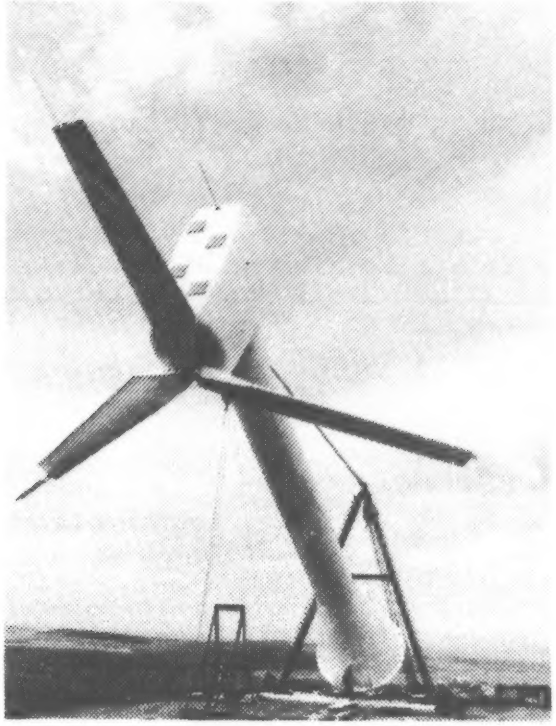
A standard industrial controller is used to supervise the wind turbine operation. This unit continously monitors the condition of the wind turbine, the wind velocity and the grid connection. In the automatic mode, the controller operates the machine according to the prevailing conditions. Manual operation is also possible.

The system is fail-safe since a failure of any component or sub-system will cause it to shut down independently of an instruction from the controller. Similarly, a failure of the computer system will cause the machine to shut down.

In addition to its prime function of control, the computer also records a continuous log of the wind turbine operation.

TRANSPORT AND ERECTION

The HWP-300 is designed to be suitable for transportation to, and erection at, remote sites without the use of large cranes. The tower, nacelle and rotor can be assembled on the ground and winched upright. The nacelle machinery is then raised by the travelling hoist within the nacelle. The blade tip mechanism can be serviced from a folding platform which extends from the midpoint of the tower.



Lifting the Howden HWP-300 into position at Burgar Hill, Orkney

Tip servicing using the folding platform

HOWDEN PRODUCTS AND CAPABILITIES

JAMES HOWDEN is one of the world's leading companies manufacturing air and gas handling equipment. Major products include centrifugal, mixed flow and axial flow fans, large air preheaters, and gas circulators for nuclear power stations.

Over 125 years of experience in the power industry — designing, manufacturing erecting and servicing equipment based on technologies similar to those of wind turbines — are backed up by a continuous research and development programme.

The HOWDEN group of companies has worldwide distribution and service facilities. We can install and service wind turbines anywhere in the world.

JAMES
HOWDEN
& COMPANY

Printed in Scotland

EXPORT MARKETING OF THE DELTX WINDPUMP

Ian MacGregor, President, DELTX Windpump Corporation

I would like to start off first by apologizing on two counts. I am more a salesman than a scientist and I may not live up to the technical expectations that you have of me. The other thing is that our system isn't very technically sophisticated. It certainly won't be among high scientific achievements, but we think that sometimes simple things make more economic sense than complicated things. So I'd like to tell you a little bit about it.

There are three things that are pretty important about this company.

First, we are not in the electrical business, our main interest is pumping water. We don't have any interest in generating electricity except as a byproduct through a hydro-electric system.

Second, we think marketing means international, especially if you are based in Canada, because the energy prices are so low here that it is very difficult for any system to compete. In Alberta we pay about $0.05 a kilowatt-hour. We don't think any wind system can compete at those prices. We are concentrating primarily in the US initially. But, as we demonstrate our technology, we plan to get into the developing countries market.

Finally, I'd like to tell you what we think the water pumping market is, why we've got a unique product that's well-targetted for that market and how we are organized to go after it.

We think this business looks a lot like the oil business which is where we came from. I started a company named ABAX in a double garage about twelve years ago. That company grew to about 250 employees and is the second largest fabricator in Alberta. We got interested in wind water pumping technology because it used the same type of manufacturing methods that we had developed in the oil business.

We think it looks a lot like the oil business because you look around, you prospect for something and then, after you think something's there, you measure it and try and find it. Once you find it, you have to find a cheap way to convert it. I think the key word is "cheap". If you can't convert it economically, there is no business.

We spent the last seven years working on it, trying to accomplish a method to convert it cheaply. This work has forced us down a quite interesting but very narrow segment of the market. If you think about it a bit, it's a pretty large market. Every time you turn-on one of these things, a pump starts somewhere. Ninety per cent of all the water that's consumed is used for agricultural purposes, and almost every drop of that water is pumped at some point in the consumption cycle. So, even though it's a small part of the electrical market, it's still a pretty interesting business.

There's a couple of different ways in which water is pumped.

In Canada we call this a hydro-electric power generating station. In California, they run it backwards and call it a pump station. There are a number of these throughout the US. This one uses about as much energy as 300,000 homes do, a fairly significant pumping load.

The other place where pumping occurs is in remote stand-alone applications which are typically diesel driven. They are off-grid where usually a farmer is trying to get water to his land.

We are after both parts of that market. We're after the major pumping installations and the remote installations. We've got two basic product lines to go after them.

How big is that pumping market?

It's $130 billion annually for that type of pumping energy, which is big enough to be interesting. There is a fairly significant market there and we are well-suited to go after it.

What does that mean for DELTX?

We can go after that market because we've done a significant amount of testing on our machine. We can compete economically right now, straight up on an economic basis, without tax credits or gimmicks. Our advantage is the simplicity of the machine, the size of it and the maintenance of it. If we can get one per cent of the market, that's $2.5 billion of sales which is sure enough to get us interested.

How are we going to do it?

This is our Wind Pump 50. It's about 135 feet tall to the tip of the 16 metre diameter rotor. It weights about 50 tons. It's different because it's all made out of steel, using fairly low technology. We're designing tractors rather than airplanes. This machine is rated at 205 kilowatts and is capable of pumping 25,000 US gallons a minute in a 30 mph wind.

The design has some novel features.

First is the blade. It's made from thin flat steel sheets that are folded once. It's not a complicated aerodynamic shape and can be built by just about any welding shop anywhere. The whole machine design is really like that.

Another of the innovative features on the machine is that the load can be adjusted so the aerodynamics operate at peak performance over a very broad band of wind speeds. There's a reciprocating drive shaft that causes a beam to rock back and forth. The pumps are located so that two of those rods top and bottom slide back and forth to drive them. The load is adjusted by moving the pivot point on the connecting rod. This is done with a farm-type hydraulic system consisting of a hydraulic piston with a leak in it. If the machine is going too fast, the leak isn't significant and so the screw inside turns one way, and if the machine's going too slow the leak becomes very significant and the screw turns the other way, driving the connecting rod out. By adjusting the size of the leak, the aerodynamics operate at their peak performance level over a very broad band of speeds. This results in about twice as much energy as obtained without this system.

The second thing is that we don't have a generator, we have pumps. There are no gear boxes or complicated things like that. This system is a totally reciprocating system. You used to see this kind of thing about 1850 for canal pumping in England. That's the piston in one of our pumps. It's 4 feet 3 inches in diameter. It has a 4 foot maximum stroke. It's a pretty simple thing with a leather seal. That's a chunk of cow-hide that's wrapped around the outside of the piston with a couple of rubber flapper valves. It's a pretty simple low tech thing, designed to go with annual maintenance. To date we've seen that we can do that.

This is our small machine, showing the sequence of erection. It goes up a lot like the Howden system. Just a Gin pole bolt to pull it up with a 'cat' instead of a winch.

This is our first commercial machine. It was sold to Ducks Unlimited. We put it up in June of this year. We've pumped 50 million gallons of water with it so far. We are quite pleased with the operation with between 3 and 4 million cycles on it to date.

The pumps again, we use a lot of oil field technology. We use cables to drive it down from the top and just horse's heads like you see on any oil field pump jack. The pumps are sitting down in the water. That's it up. The maximum rotational speed of this machine is about 200 rpm in a runaway condition and it normally operates much slower than that. And that's the water.

This slide illustrates what we think other people are building and what we are building. It's a totally different business. We're not in the electric business. We're not in the airplane business and we don't think we 're going to see the same type of problems.

Just to go into a little bit of depth about the kind of applications we are after. We're after two basic things.

One of them is to put a reciprocating pump down at the bottom of a water well and drive it directly from the top. This in places like the Ogala Aquafer in the U.S. where you are pumping from a depth of about a thousand feet.

The other type of business is pumping water into a hydro-electric system. It could be combined with an irrigation system to achieve really interesting economics. You could generate electricity as a by-product while supplying water to the irrigation system as the main source of revenue. With two sources of revenue, the economics are just outstanding. A system like that can pay out in about 5 years, not tax effected, which is quite important.

Compare it to the familiar 16 foot diameter farm windmill, which is a real large farm windmill. Think of that windmill producing one unit of energy, then our small unit produces about 15 times as much and our large machine produces about 1500 times as much. Originally, we started out with a 15 foot diameter rotor and a 52.5 foot or 16 metre rotor.

We can't find really high energy wind sites so we are optimizing the machines to work in a 10-11 mph regime rather than a 16 to 17 mph regime. After looking at a lot of sites, we couldn't find wide applicability of a machine that needed 15 mph or 16 mph winds to make it work properly. So we are in the process of re-designing the unit, optimizing it for a much lower windspeed. The first prototype is under test in our shop. We put a bigger rotor on the same mechanical drive system and we've standardized the machines for 20 and 65 feet. That gives us about a 30 per cent improvement in the economics.

One of the targets for the Windpump is to sell $50 million worth of equipment by 1988, $50 million annually, and to do that at a gross margin of 40 per cent. We think it should be a damn attractive business. We think it can be as big as a small car company, once we get into full production and we're really excited by it.

A lot of people walk around and say they can build big businesses, so I'd like to tell you about the background of our individuals, investors and shareholders to establish a little bit of credibility with you.

We've really got a unique organization for a couple of reasons.

First of all we've got a group of experienced venture capital companies with deep pockets. A business like this uses up a tremendous amount of cash. We've spent between $2.5 and $5 million to date, depending on when you cut it off. We spent some government money to get the thing going. We think it's going to take another $5 million before this is a business. So you have to have people there who can fund you and that are committed to getting into the business. We think we've got that with Ontario Energy Ventures and the Alberta Ventures Fund. They are experienced in start-ups. They understand that these things take a long time. They are financially motivated and believe in the business.

ABAX is a company I started about twelve years ago. It's a manufacturing company and it has a fair enegineering capability and a fair capability to build. One thing a company like ours doesn't need when it's starting up is to try to build a manufacturing capability at the same time it's trying to develop the technology, test it and sell it. What we've done is contracted ABAX to provide all the manufacturing for us. ABAX's present shop could build two large wind pumps a week very easily and it wouldn't be any stretch for them at all. Once you establish the market and are convinced that everything works properly, we think it's quite important to be able to sell a lot of them in a hurry so that you don't have a lot of competitors there.

Another thing that's different about us is a very experienced management team. I'd like to talk about some of the people in our management group.

Myself, I'm an entrepreneur and a salesman at heart. I've been educated at the University of Calgary, in Mechanical Engineering and at the Harvard Business School. I'm not a technical person, although I understand some of the technical aspects of our equipment.

Jerald Alexander was previously in the acquisitions area of Dome Petroleum in a very senior position. Jerald was educated in engineering at Stanford and in operations research. Between the two of us we are kind of the business development guys in the company.

Emil Sanden, our Vice President of Engineering, was previously Assistant Deputy Minister of Highways in Alberta. He's got a number of awards for innovation in bridge design and, believe it or not, there's a lot of equivalent things between bridges and windmills.

Our Chief Engineer, Jack Gittens, who was previously with Montreal Engineering, has had a lot of experience with building very large steam generating sets in England. He applied this technology, got it started up and commissioned them in Canada.

We've got a pretty talented management group to put it together which is THE key. You can't be an inventor and get into this business in a significant way. At least we don't think you can.

Where we've come from, where we're going and how we plan to get there.

We started off about seven years ago with an initial idea. It originated with John Kentfield at the University of Calgary, whom I'd met through graduate courses I had taken in Mechanical Engineering there. He had come up with interesting ideas in aerodynamics and pumping systems. It looked like a good product for ABAX in our shop. We decided to spend about $50,000 and build a prototype and test it. We sent the aerodynamics on that prototype down to the National Research Council, Ottawa wind tunnel. We were encouraged by the performance data we obtained, so we went the next step, which was raising funds to build a full-scale prototype.

We were supported by the Energy Resources Research Fund, which is a joint funding effort by the Government of Canada. The Alberta Government and ABAX put about $1,000,000 into it and we built a prototype.

The next step was to put up a small field demonstration for a friendly customer, namely Ducks Unlimited, an environmental group that raise Ducks all over North America. It was really important early on, to get it out into a customer's hands. If you have your own people running the machine, you don't find out very much, namely, what breaks when you don't look after it. You have to deal with the customer complaints. You have to satisfy somebody who doesn't care, who's not a wind person, who just wants some water. It is pretty important to get it into a customer's hands to find out what goes wrong with it and other kinds of problems. It cost about $2.5 million of our own money to get to this point, and then a substantial amount of government money along with it.

That's where we are right now. Our next step is to put up a full-size field demonstration unit. We're going to do that east of Calgary. We've signed a letter of intent with Ducks Unlimited to put up this machine. It's going to be pumping water to flood about 2100 acres in order to raise about 60,000 ducks on it. We're looking forward to that. It will cost us about $3.5 million to get there. That's the site. It's just a lake off the irrigation system. We'll be putting that machine up in the first quarter of next year.

The next step is to put some of these things at an existing hydro installation. We want to do it in Alberta and we think that TransAlta is going to help us do it. TransAlta is the largest utility in Alberta. They own nine hydro installations in southern Alberta. We are working with them on a joint feasibility study examining the increase in capacity factor at one of the hydro-electric dams in southern Alberta. Most of these dams are sized for the spring run-off. Consequently, they operate at about 30 per cent of name plate capacity. Because the rest of the electrical infrastructure is in place, by recirculating water we can provide additional demand power quite cheaply. I think it's going to take about $9 million. We plan to put up about 12 units west of Calgary. That will be in the third quarter of next year.

This is another site that we've optioned in Southern Alberta. It's the site of an existing dam over in there somewhere. It was a cooling pond for a gas plant. It was real foggy with ice crystals the day I took this so you can't see the gas plant which is up in here. A fellow is now converting this into a fertilizer plant. We have an option on this site over here to sell him electricity to run his fertilizer plant over there. He owns the land which he is providing to us for free. We hope that will happen some time in early '86.

Right now, I'm out raising money. We're looking for about a million dollars to keep the thing together this year. We've got excellent indications from a number of outside groups that we're going to get it. That's what I'm spending most of my time doing right now.

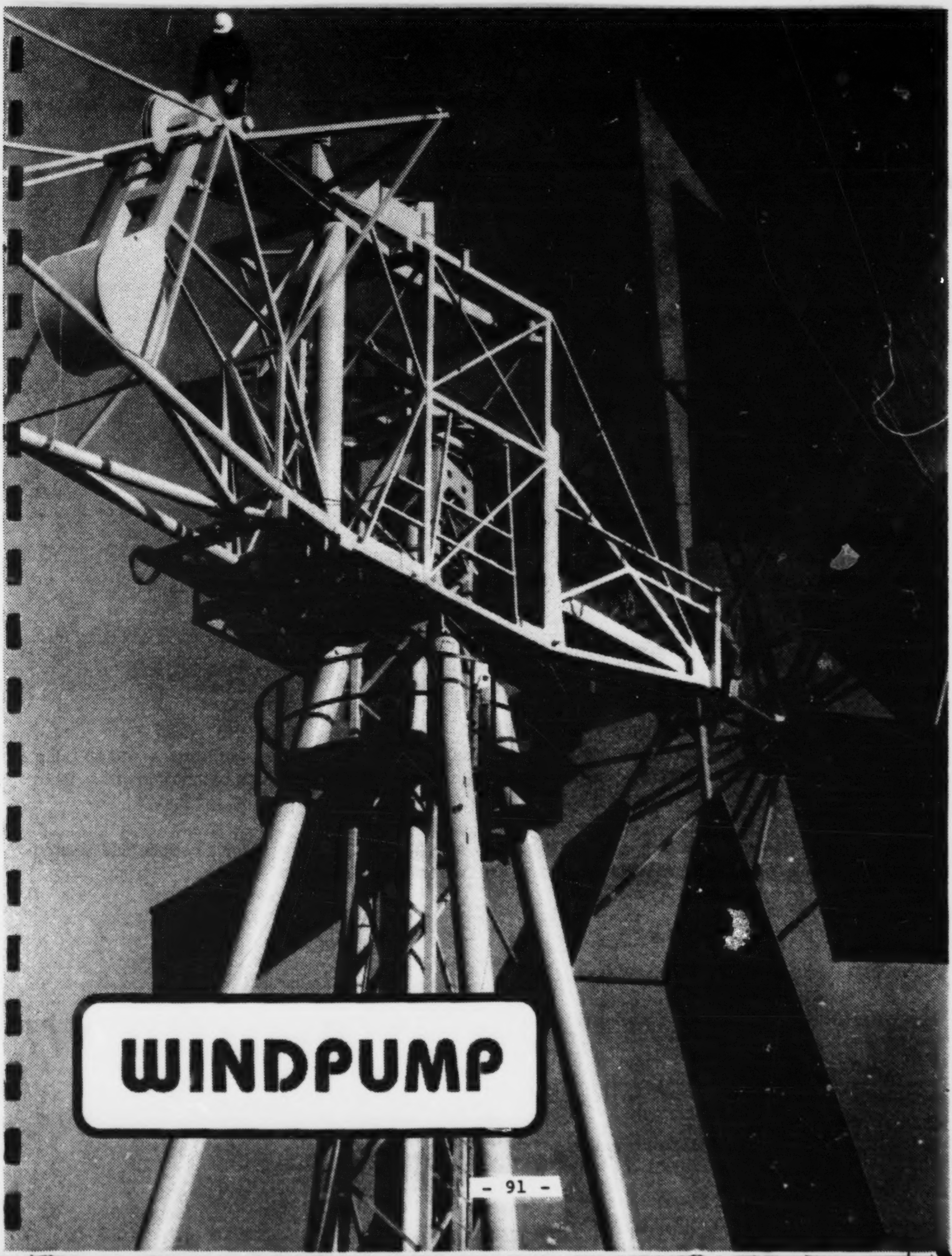
Some of the other sites we have.

We have optioned a site on MOLKAI in Hawaii. Over the top of this hill there is 15,000 acres of land that used to be irrigated. There's about a 600 foot cliff down to the water. MOLKAI is one of the most expensive places in the US for electricity. They are currently paying $0.27 US per kilowatt-hour at peak. The 15,000 acres on the other side of this hill have just been abandoned. It used to be irrigated by pumping water over the hill, but as energy costs started to rise they just couldn't afford to do it any more. They've made the site available to us and we are going to try to interest a wind farm developer out of California to go in with us on the project. We're going to pump water up over the top of the hillin order to rehabilitate that land. We plan to put in about 100 wind pumps, 65's, at this site in 1986. We've got the site option now, as I said.

We've looked at some other sites in Hawaii. This is a cinder cone that we would use for a storage reservoir. We'd put windmills around the outside of it. This is on the big island. It's a place called the Kahua Ranch. It's got about a 22 mph annual average wind speed, a really outstanding place. Hawaii is a really good place for us because one side of the island is a rain forest while the other side is a desert. Somebody has to pump the water over to get it to the valuable land on the desert side. We think that's us.

This is a site where we are currently negotiating to install about 15 machines. The fellow with whom we are negotiating is Monty Richards, he's the owner of the Kahua Ranch.

This is another site on the big island. It's a place called



WINDPUMP

The **WINDPUMP 50** is the largest direct wind pumping system built and operating anywhere in the world. In a 30 mile per hour wind at 30 foot lift, this unit is capable of pumping 24,000 gallons per minute.

In locations where the average wind speed exceeds 12 miles/hour, the **WINDPUMP 50** provides a proven, reliable, cost competitive energy source.

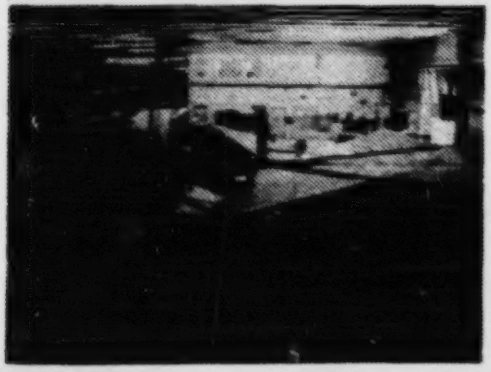
The prime uses of WINDPUMP Technology are:

- **irrigation pumping** — from primary canals and aquifer water sources
- **municipal water supplies** — from rivers and wells
- **hydroelectric power generation** — using wind pumped water at existing water limited facilities or at new stand alone installations
- **sewage treatment** — for aerating and coarse sewage pumping
- **stripper class oilwells** — for remote or marginal oilwells where large quantities of liquid must be lifted to recover relatively small quantities of oil

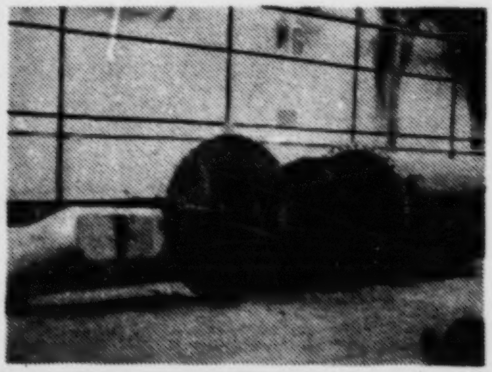
WINDPUMP is prepared to install and operate pumping stations to client specifications and to base charges for this service solely on the volume of water lifted. Savings on energy costs will be from 10 to 30% depending on conditions such as windspeed and project scope.

The client benefits through immediate reductions in energy charges, long term freedom from energy price escalation, and elimination of technical risks associated with a wind system.

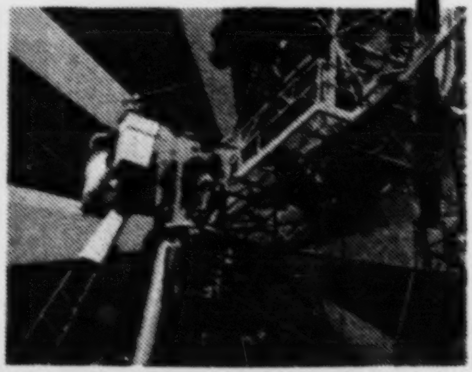
MANUFACTURE



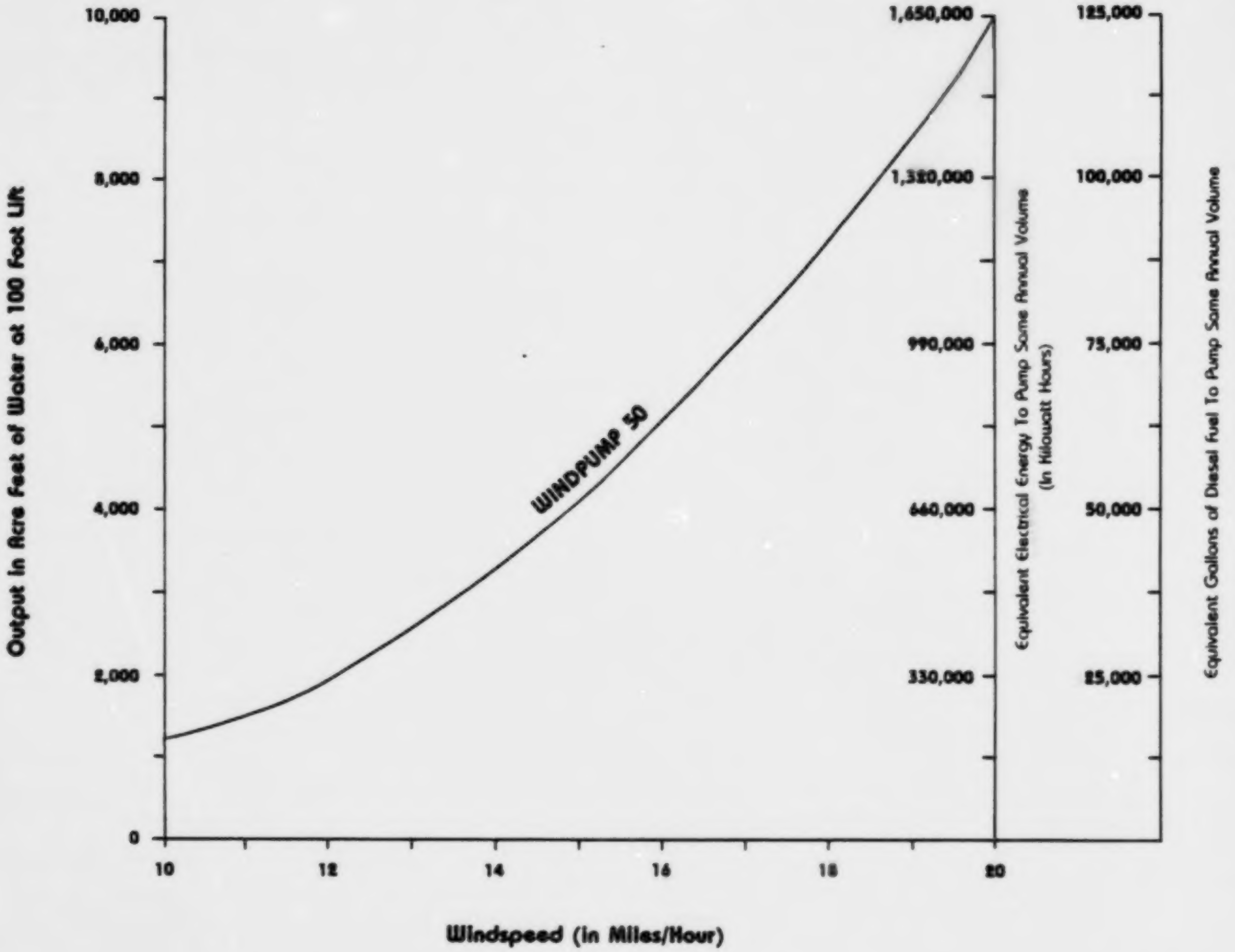
PUMP



ERECTION

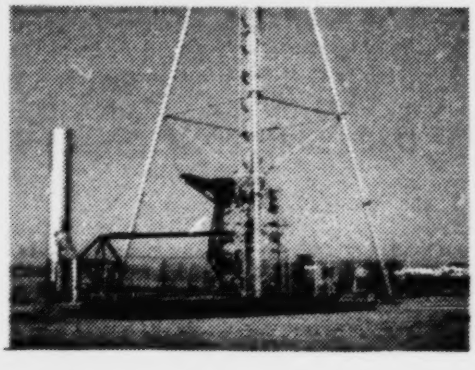


Annual Energy Produced by WINDPUMP 50

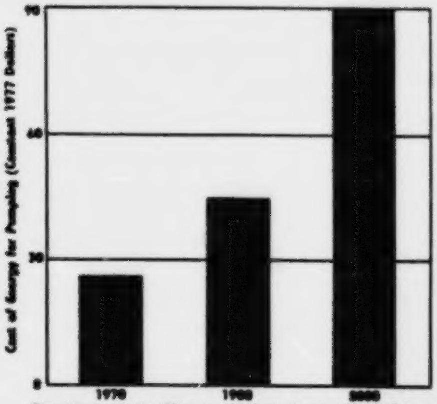


Using common rating methods, the **WINDPUMP 50** is comparable to a 350 kilowatt rated wind electric turbine driving an electric pump.

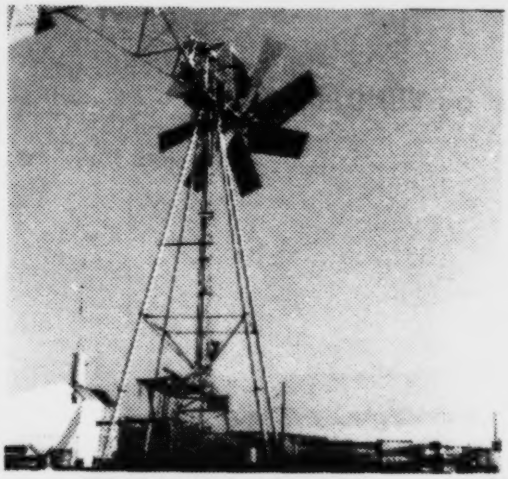
REMOTE LINKAGE TO PUMP

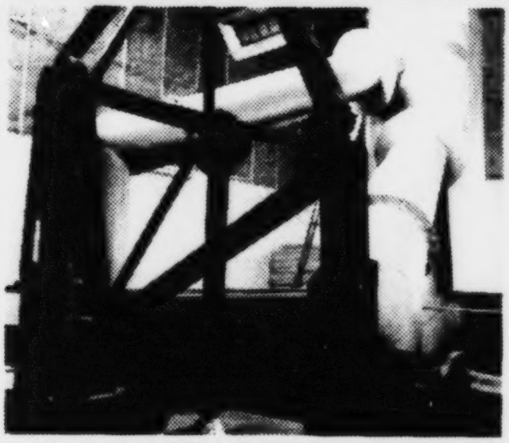


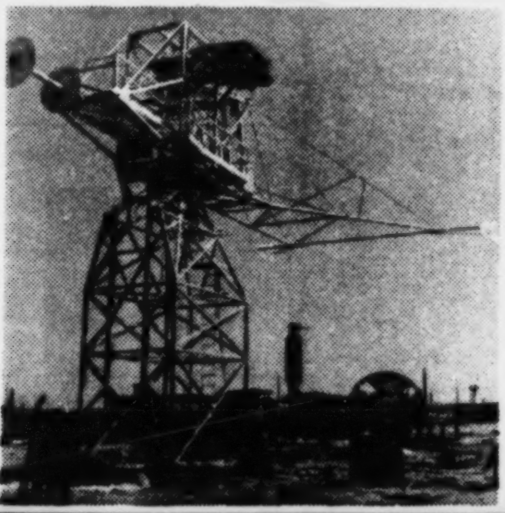
FEATHERING IN HIGH WINDS



Diesel fuel costs for lifting an acre foot of water from 200 feet
(Source: Scientific American - February, 1980.)



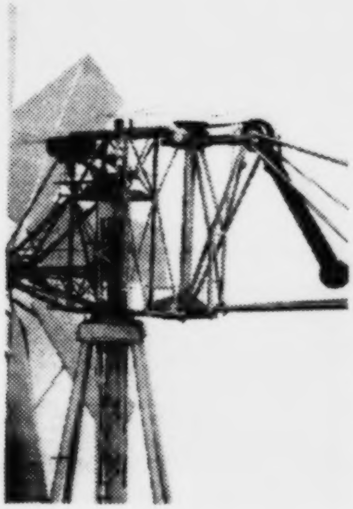


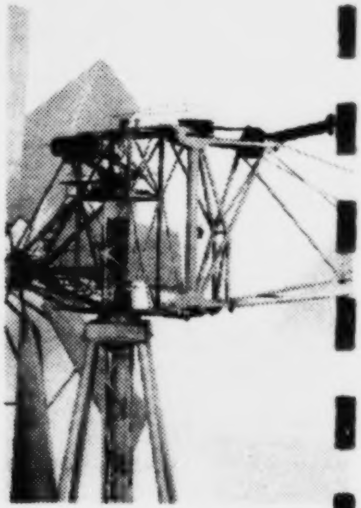


SPECIFICATIONS FOR

WINDPUMP 50

- Patent protected rotor
  - diameter - 52.5 feet
  - speed - 7 rpm to 30 rpm
- Overall height — 130 feet
- Maximum survival wind speed — 120 mph
- Pumps — two, direct displacement
- Mechanical linkage allows location of pumps up to 1,000 feet from turbine
- Construction — welded steel
- Foundations — 20 inch bored concrete piles
- Erection — self lifting to raised position using winch truck or 35 Ton hydraulic crane
- Design life — 50 years
- Operating range — 7 mph to 60 mph
- Governor — mechanical, failsafe, patent protected system





Deltx WINDPUMP Corporation

Hawii. It's just a little 250 kilowatt hydro site that they're rehabilitating. There's some hydro-generators in here. They are water-limited at this site. We can go in, pump water around in a circle and just supplement it. It's quite an attractive economic deal at that point. All of these sites should show less than a five year pay-out. We think these are the kind of numbers that make sense to outside investors.

Thanks very much.

QUESTIONS AND ANSWERS OF PANEL

Q. One for Lawrence Schienbein and one for Duncan Hume. The question for Lawrence. I was a little confused, not even sure if I caught something that you said correctly, Lawrence. In the spectre of stresses in the 500 kilowatt machine, did you say that the 1P peak was predominant at the B3 position whereas 3P was predominant at B1, I think it was the B1 position at the root? I'm a little confused as to why it should be different in the two places, if I caught it correctly.

A. I don't think I said that. But, in fact, I don't think that's true. I think the slides illustrate that the 3P is dominant at both locations.

Q. Okay. For Duncan I had a question. It's just a matter of curiosity. The cables coming down, that are rewound if you go more than three revs, how many times has that happened? Does it happen very often?

A. It hasn't happened once in the year that it's been operating, no. There's a very strong prevailing wind and it just doesn't go round and round.

Q. I remember hearing something the same from the old Gedser mill a long time ago. I think it ran for years and they never had to undo the cables and untwist them.

A. It's still actually at neutral, I was up there the other day. It's at neutral right now.

Q. A question about markets. I was interested to hear Deltx talk about markets. I'm wondering if DAF Indal Ltd. and The Howden Group Canada could identify what sorts of markets they are looking to in the near term. In terms of what windspeeds they need and what cost per kW-h they require to compete.

A. Well, that's a fairly general question. We (Howden) have been approaching it in a number of different areas. The first thing that one gets into is remote sites. Now remote sites are expensive to erect and service wind turbines at. And we are looking at those, we think that we can produce power somewhere in the $0.20 per kilowatt hour range for a remote site. We've also got a wind turbine farm going up in California. These are induction machines. They are much cheaper, they're skinned down, they have much longer blades. They are designed to catch low windspeeds. Originally, we thought that we would have just the range of 'off- the-shelf' machines. But actually when you get down to it and start looking at it that's not the case. You need to design your machine for every different circumstance, especially if there's a lot of machines and the overall cost is going to justify that. So, really, you're going to see, I think, a special machine for each location. If you have a lowish windspeed, you're going to have long blades. It puts the cost up but it still may justify the overall installation. So we're looking at everything.

A. DAF-Indal's marketing activities are quite extensive in fact. We've had full-time professional marketing for wind turbines for almost three years now and our activities are obviously focussed in on both the wind farm and the remote market. The wind farm market is not a very simple market to address, because the targets that you might have for the cost of energy for a particular project, particular location, will be different than for another site. And a lot of it has to do with the application of the tax credits and the way the financing for the project is constructed. So there is no good general answer to what cost per kilowatt hour target has to be achieved for that particular market. What we do know is that there are markets, that there are projects, in both California and Hawaii that we have worked on where our machine would be fully cost competitive. There's no problem with that. The remote market is a market that will take a lot longer to penetrate, because there is a natural reluctance on the part of any business to go into high risk single machine type of installations, because what you end up with is one or two machines scattered in isolated locations, perhaps balanced by one or two wind farms that the company is also engaged in. And it's easy to see that the revenue and the contribution to profits by one or two pioneering type remote machines is not going to be significant when compared to wind farm projects that are established in what seems to be a much lower risk environment. So I think that marketing the two types, or going after the two types of market is not only a matter of technical requirements, but also the timing will be quite different. Another aspect of our marketing programme is the whole question of licenses and we are also pursuing, around the world, the possibility of licensing our products for specific geographical areas and if you are interested in more of DAF's marketing work, I would encourage you to talk to Mr. Vincent Lacey who is here today, our product manager with his hand up in the back and if you can't reach him easily you may find him most of the time at our booth over in the display area.

Q. Just to continue the previous question. Could one of you tell me how much we could expect in terms of dollar sales for the next five to ten years. Is it a real big market? Is it a very small one?

A. (Howden) I don't know. We think it's a pretty big market, but I don't have any dollar numbers, I'm sorry.

A. I think a conservative estimate for the share of the market that DAF-Indal believes it can capture over the next ten years would be somewhere between $100 and $200 million.

Q. I just really want to make a comment on Ian MacGregor's slides. It appalled me to see that he had placed the windmill down in the valley in the lee of the dam. Please give more consideration to putting them on the hilltop. Perhaps it's a question...How much consideration are you giving to site selection for these pumping windmills?

A. I guess, obviously, we'd like to place them in the best sites we can. That slide was done by a marketing person, not a scientist, as I said. We have a full-time person who actually runs our economics. You know, a lot of people spend a lot of time trying to figure out the best possible wind site and what we like to put into the equation is how much the foundation costs and how much the pump costs and how much the tower costs and we have a very detailed and complete, we feel, computer program that allows us to optimize all these facts and put the thing together. We were not looking for a site that's 16.7 mph. We might be looking for a site that's 13 mph and has got cheap foundations, a cheap pump foundation, you know. Our business is really economically driven, so we're optimizing a number of different factors. Windspeed is one of them.

RESEARCH TEST AND DEVELOPMENT

DENMARK'S TEST STATION FOR WINDMILLS

Carl Jørgen Christensen, Risø National Laboratory

In this talk I shall try to give you an impression of what has been going on in Danish wind energy and especially at the Risø test station. I will start by describing the work on the Test station.

First, a few words about danish energy policy, especially as far as wind energy is concerned. We have, since 1980, had a system of subsidizing wind energy and other kinds of renewable energy systems in the way that a private customer who decides to buy a machine of any of these types, can get a reimbursement from the government of the order of 30 per cent of the machine price. There is a catch, however. The condition for getting this subsidy is that the equipment has been licensed by a test station. For windmills, it happens to be the Risø Test Station which does that licensing. Therefore, this is a rather important part of our work.

Very roughly, our work can be categorized as licensing, testing, research and consultancy to industry.

In connection with licensing we do an engineering review where we give a rather broad consideration to many aspects of a wind machine. Essential is, of course, the strength of the various components or rather all components. It's important to make sure that there are no holes in the chain that transfers the big forces to the foundation (fig. 1).

We judge the production capability - does this machine produce something that corresponds to the price of the machine?

There are questions about power regulation, that is, how does it regulate power loads and how does it prevent overloading at high windspeeds?

We look at safety systems and here especially the brakes, which are very important. All accidents on any machine that has been licensed have to be reported back to us. These reports are then used to establish the need for further development work. They are a central part of our basis when we choose which kinds of research projects to work on.

So far we have mainly concentrated on making sure that if you buy af windmill, it doesn't fall down, it does work most of the time. It has been our point of view all the time that if wind energy is going to be a viable alternative to other sources of energy, that we know to day, the first and most important thing is reliability.

Testing. In many cases, we want to test the machine, because we are not quite sure that by just looking at drawings we know everything. Therefore, we have defined or developed the standard test programme. It is meant to give as much information as you can get about the essential features of the machine by the use of a measurement systems that is as simple as possible (fig. 2).

We are testing for any kind of function that is claimed by the manufacturer. We test for whether it is there and whether it works sensibly. It's a matter of measuring the power curve in order to evaluate the production capability of the machine. We look at power regulation, especially power limitation. We look at the loads at start and stop, the starting capability of the machine, brake efficiency, loads during braking. These things are quite important for the durability of the machine.

Research. Even though we have concentrated mostly on getting machines reliable, the emphasis is changing somewhat. We think that, by now, Danish machines are reliable, so we can concentrate more on improving the performance of the machines. Therefore, rotor aerodynamics is important.

The problem with aerodynamics is that, to a certain degree, it's more an art than an exact science. We would like to be able to do an accurate first principle calculation of the aerodynamic performance of a rotor using existing profile data, but nobody can do that to day.

Our main emphasis is on establishing semiempirical calculation methods, that allow us to minimise the need for doubtful calculations, when doing rotor design. I will show an example later. Another important research item is fatigue life and rotor dynamics.

Consultancy work for the manufacturers is an important part of our work. This helps us to communicate our research very efficiently and gives a role in the rapid development and the success of Danish windmill industry.

The success of the industry is illustrated in the next two graphs, based on information we have available through the mandatory reports of accidents. Fig. 3. shows the failure rate per year of the machines installed at any given time. As you can see, we operated with an annual failure rate of around 50% back in 1979. This also fits pretty much with the general impression at that time, namely: you bought a windmill, and shortly after it would fall down dead. The situation today is fortunately much better. For 1984 the annual failure rate is down below 1%. That's how it is. So by now a satisfactory reliability has been obtained.

Another proof of the improvement in quality is shown in fig. 4. From power production data which were assembled by our Danish union of windmill owners we have calculated the average production during the past year of the 55 kW machines operating at any one time. So you have a sort of floating average. What you see is a factor of 2 improvement in average yearly power production for 55 kW machines over this period. This reflects the higher reliability and availability of the machines. But it also reflects that we are getting smarter at choosing the right sites for windmills. Particularly the Risø wind atlas for Denmark has shown up to be extremely valuable and is used extensively to prevent bad sites from being used. This, of course, also helps improving the power production.

Then you could ask the question, "Why have we succeeded in improving things so rapidly"?. Next, I will give technical highlights of the important improvements, that have helped further the development. Let me first show what we call the Danish concept. It so happens that most manufacturers make machines that are pretty much built after a traditional danish concept, featuring a three-bladed upwind rotor, stall-regulation, active yaw, grid connection by an induction generator, and the double brake system.

The historical background for this design is the Gedser machine, (fig. 5) a 200 kW machine which ran for ten years without major trouble, though not without trouble, mark you the difference. It was refurbished when we started studying wind energy again in the seventies. Because of the fact that it had worked without major trouble it was worth looking at again.

Fig. 6. is just one modern example of the danish concept from one af the big factories, a 55 kW machine.

But to come back to the point, why has it been possible to improve? Part of the explanation is the strong cooperation between industry and the Test Station. We have been lucky to build a system where people listen to each other and discuss the problems. Furthermore, by means of the licensing arrangement, we know what is going on in the industry and can push for better machines. This sets the scene for some very fast development. Our licensing is given for only one year at a time. Each year we are, in principle, free to change the requirements. Even though a manufacturer got a license last year, he can't be sure that he will get it this year. The result is that if we find problems that we have to do something about, the manufacturer has to improve his design accordingly very quickly. In this way you have a fast spread of knowledge.

Many of the problems, which we found, have given rise to some kind of research. We do very applied research and we are very likely to use empirical methods. This is because we are not a free research laboratory. We are under the influence of manufacturers who want to get answers tomorrow. They don't want to wait for several years to get fancy research programmes run through. So we have to live with empirical solutions. We don't mind that, especially when we see that it actually works.

Let me give you a few examples of problems, whose solution have been essential for the development in quality. Even though most danish windmills were and are stallregulated, it was quickly realized, that nobody could design correct stallregulation. If a 55 kW machine yields 200 kW or so, you have an overload problem. Aerodynamic theory is not good enough to predict the stall characteristics of a new rotor design.

We undertook a measurement programme with a mind on finding simple methods such that once you have designed a rotor blade you should be able to predict the performance of that blade in any kind of configuration you choose, when it has been tested once.

We measured the stall characteristics at different speeds of rotation and rotordiameters using the same blades. When comparing these measurements with aerodynamic calculations it is possible to deduce empirical corrections to the known profile data. Using these corrected data, aerodynamic calculations on different configurations with the same blade yield good results. Therefore stall characteristics can be predicted well once one power curve measurement has been done on the blade. Fig. 7. gives an example of the fit, that can be obtained with these corrected data. Fig. 8. shows a checkmeasurement of the flapwise root bending moment. This extra measurement adds more confidence, that it is allowable to assume, that the aerodynamic rotor model is correct and only the data needs corrections.

We can now say that all Danish stall regulated machines will stall at the power, where they're supposed to. This was pursued because of accidents caused by overloading the machines.

Another example I can mention. It was popular in the beginning to regulate power by yawing the machine out of the wind at high wind speed. Sometime we got suspicious that this kind of regulation was the reason for many accidents. After some discussion, we decided to forbid power regulation by yawing. Later on we did some measurements to show that we did right.

What you see here (fig. 9), is the power performance for different windspeeds, one set for each windspeed, at different yawing angles. At low windspeeds, it goes like you would expect, that when you yaw out of the wind the power will fall, which is what you want. But, lo and behold, when you go up in the stall region, you actually go the wrong way, increasing power when yawing out of the wind. That was one of the reasons that power control by yawing caused breakdowns.

But that was not the only problem. Dynamic loads in the rotor increase tremendously in skew wind. In fig. 10. You can look at the band between the maximum and the minimum, essentially the highest seen load on the blade and the lowest seen load. The band is a measure of the dynamics of the blade. When you yaw out of the wind you have a very strong increase in dynamic loads. So if you run the machine for just a few hours sufficiently far out of the wind, you wear out blade fatigue life very quickly.

Another thing which was realised quickly was that the old machines were made with just one mechanical brake and the grid to hold on to the machine. What people didn't realise was that you couldn't be absolutely sure that you always had the grid. If the grid fails, which it does occasionally, and you rely on just one mechanical brake, you have to be damn sure of that brake. We felt that we couldn't be sure, mainly spurred by seeing lots of cases where the mechanical brake failed. Consequently, we have imposed the condition that there has to be two independent brakes. This has been a condition for about three years. One of them can be a mechanical brake, but the other one has to be aerodynamic. They have to be independent such that you don't get what is called Common-Mode failure. There are a lot of requirements for each brake, but I don't have to go into that.

Finally, we have defined the design load that we can apply when we check the strength of the machine. We use 300 newtons per square meter of swept area as a reasonable maximum rotor thrust to expect. We use that for checking all parts of the machine. These were examples of the kinds of jobs we have taken up as spurred by the obvious needs in the industry and which have given good results.

When we are interested in windmills there is the unavoidable question of whether wind energy has a future. As I hinted earlier, we have so far been mainly interested in the reliability. However, we are changing our emphasis to look more at the economy of the machine. This is a much more difficult thing to handle because if you are only concerned about safety you can simply be conservative and put on the big safety factor, for instance decide on a 300 N/m^2 maximum rotor load. This is actually what we have done. The result is that all the latest machines, as we see them now, are much heavier than those made in other countries. This is clearly a problem when we start talking about economy.

We think the next steep will be to become smarter in establishing more precise design criteria in the hope that we can relax the high safety factors somewhat. This will help very much improving the economy. Then you can also fiddle with the efficiency of the machines. There are lots of things that you could do.

Let me give you a very short idea of the future possibilities for improving the economy of windmills (fig. 11).

We know that the economy seems okay for small grids, specifically Wind/Diesel systems in remote areas where you pay outrageously high prices of electricity. If you have good wind sites, the economy is presumably ok. Of course, subsidies will also make the economy okay, at least if the subsidy is big enough. On the other hand, I think most people agree today that the economy is doubtful if you try to substitute for coal or nuclear or hydro energy.

But, do we have scope for improvement? I think we have.

We can make more efficient machines, I think a 25% improvement in power production is possible.

A lighter design and possibly somewhat bigger machines might make the machines cheaper.

We are in Denmark going into something that looks like mass-production. It has been going on for one year, which is not enough to develop cheap mass-production methods. I think that, if this production is allowed to continue we will see substantial price decreases.

There are a few facts one has to remember when discussing economy. That is, at the moment we are fighting extremely high interest rates and the scarcity of capital. It's the same problem that nuclear power has been fighting for years, but we are also fighting it. Capital is too expensive and too difficult to get hold of, so we can hope that lower interest rates will come in the not too distant future and that will help the economy.

There are problems with the environmental aspects of fossil fuel burning. I think we will see higher prices for electricity because of the public awareness of these environmental problems. The public will start requiring desulphurization and removal of NO_x and other polutants in the exhaust. That will cost money. Then, of course, no one knows how the fuel prices will go.

Consequently, I would say that I can see scope for something like a factor of 2 improvement in economies if the development goes as expected.

I am reasonably confident that even though we expect the subsidies to be disappearing within some years (we don't know how many), there are good possibilities that the industry is able to meet the challenge. There are some conditions though, that must be met.

It is very essential to keep up public support for research. Also, public support for a market is needed at least for some years. If you don't have a market for the product, manufacturers don't develop mass-production methods and don't improve on their machines. So, a moderately optimistic view but here are some conditions to be met.

Thank you.

Q. David Hoffman, publisher, Worldwind newsletter. I'd like to know when a wind turbine manufacturer wants to test a machine at Risø, who actually pays for that testing?

A. At the present time, the government pays via the budget they have given us. As of the first of January this will change, so the manufacturer will have to pay.

Q. Okay. All of it or just some of it?

A. Most of it. There will still be a subsidy programme that can be used to help the small manufacturers trying to get into the market, people with no money because we don't want to kill that way of getting new ideas into the business. But the ones who have business today will have to pay.

Q. Jason Edworthy, Nor'West Energy Systems. I'm curious, you said that when new ideas come on the market, you try to transfer that technology into the other parts of the industry as quickly as possible. Does this not cause problems with patent protection for the innovators of those ideas?

A. It has caused problems but by now it doesn't. Somehow we have been able to establish a good cooperation with industry, so they close their eyes. We don't go to one factory and say, hey, you have a problem here, look at what the other guy did because he has found a solution. You shouldn't do it that way, then you will get trouble. The main thing in it, I think is that we have very broad knowledge from which we can pick solutions adapted to the ideas of the receiver. We can give individual help which is different from just taking one man's idea and giving it to another.

Q. You mentioned that you believe the price might come down by a factor of two. Could you tell me what you consider to be the price of electricity from windmills, in an average site in Denmark right now?

A. Well, this is an item of discussion, but if you use all the bad conditions of today, I would say about $ 0.05 per kilowatt hour. But I would say that you should be very careful comparing numbers from one country to another. I have been in on international comparisons of the economies of energy production in different countries. You get results out that show prices varying wildly from one country to another. I don't know why. Differences in the ways different countries are administered and in accounting traditions make it very difficult to get the relevant differences out.

Figure: 1 LICENSING WORK

STRENGTH OF:
- HUB
- BLADES
- AERODYNAMIC BRAKES
- POWER TRANSMISSION
- MOUNTINGS
- TOWER
- FOUNDATION

PRODUCTION CAPABILITY
POWER REGULATION
SAFETY - BRAKES
SAFETY SYSTEM

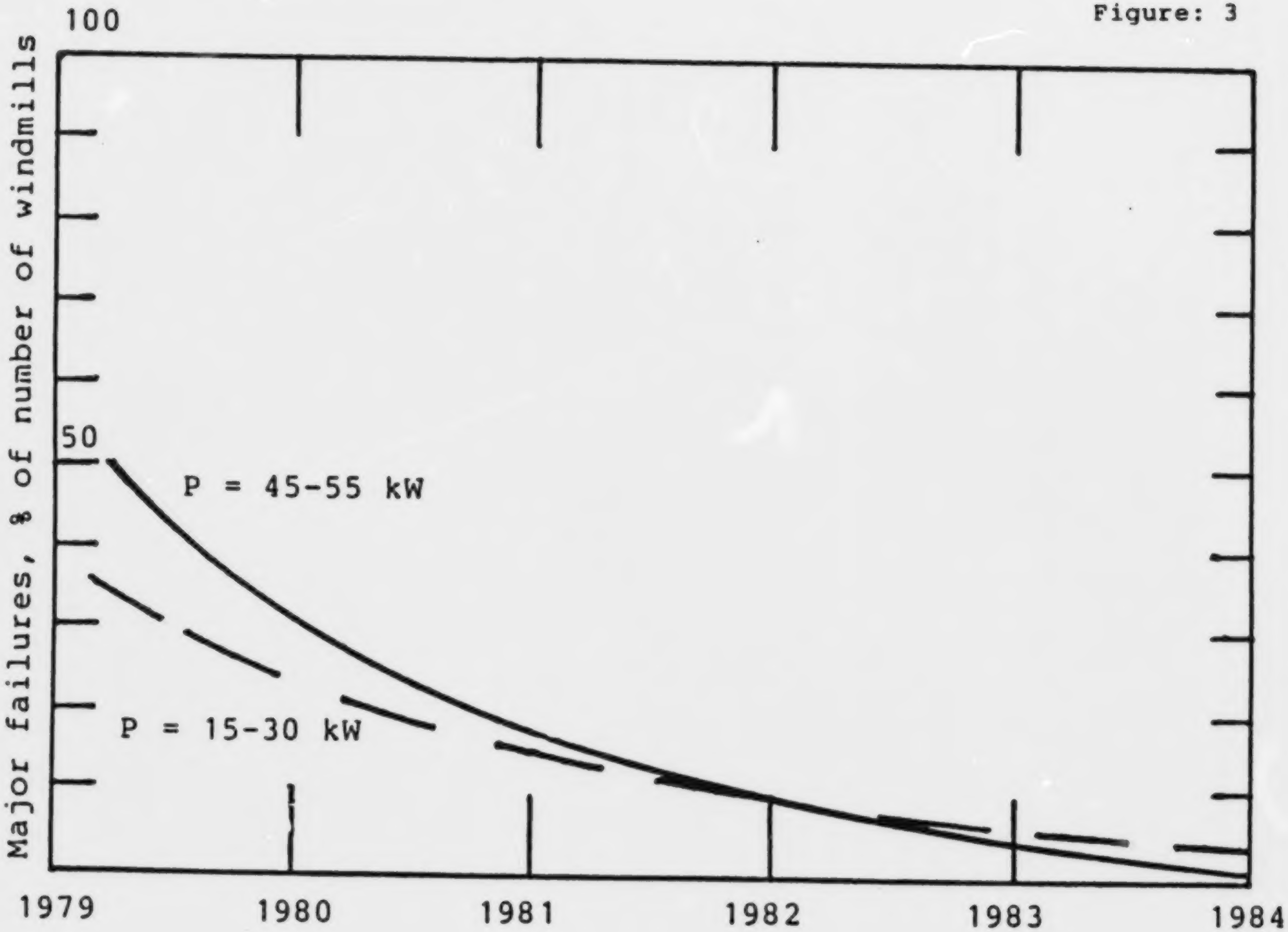
ACCIDENTS MUST BE REPORTED TO US

Figure: 2 STANDARD TESTING

THE STANDARD TEST PROGRAMME CONTAINS:

- FUNCTION AND SYSTEMS TESTS.
- POWER PRODUCTION CAPABILITY.
- POWER REGULATION (STALL REGULATION).
- LOADS AT START/STOP.
- STARTING CAPABILITY.
- EFFICIENCY OF BRAKES.
- LOADS DURING BRAKING.

Figure: 3


100
50
Major failures, % of number of windmills
P = 45-55 kW
P = 15-30 kW
1979
1980
1981
1982
1983
1984

Den. 29.01.1985 PHJ-Valby
Kilde: "Naturlig Energi"

Figure: 4

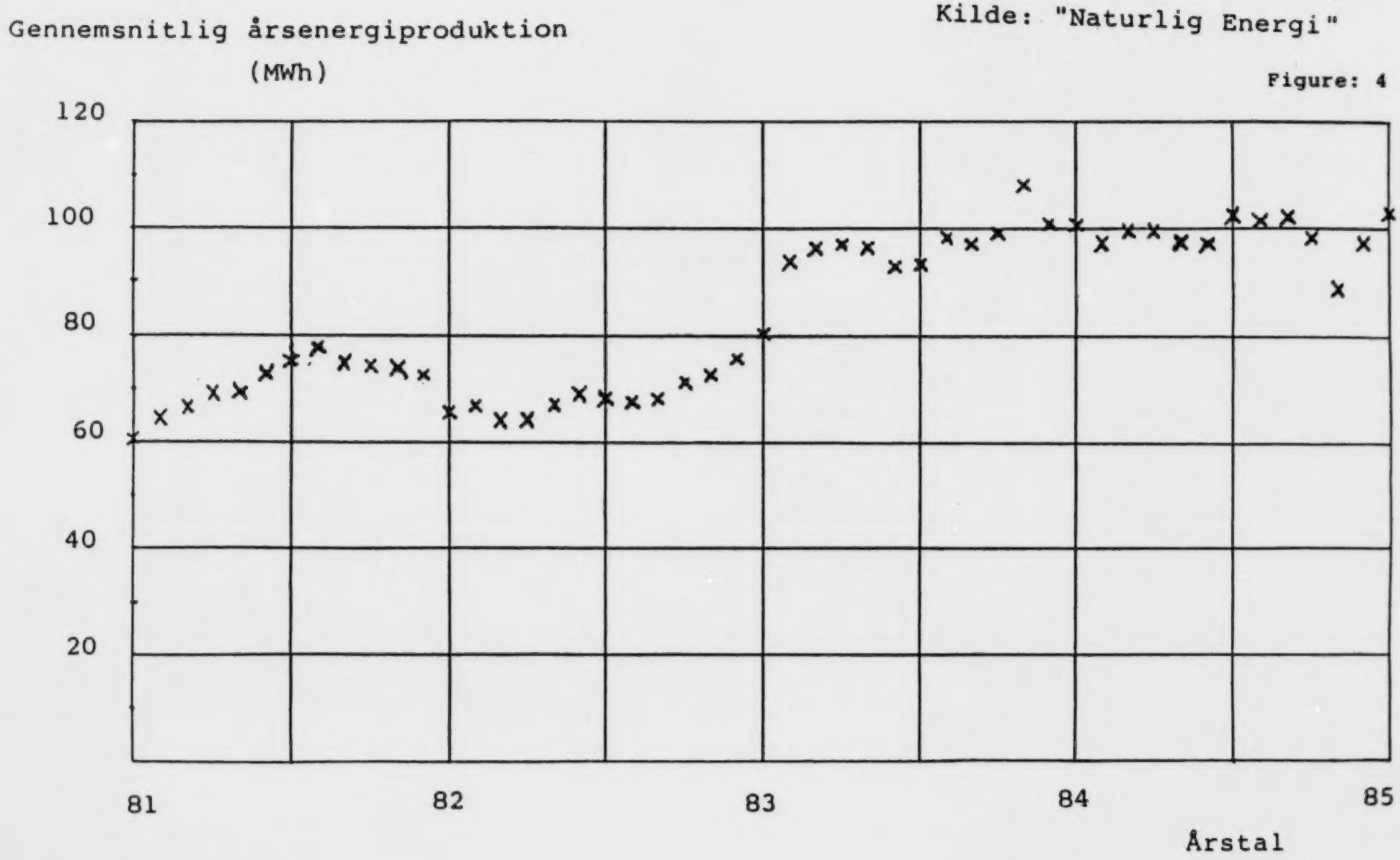


Figure: 5

Figure: 6

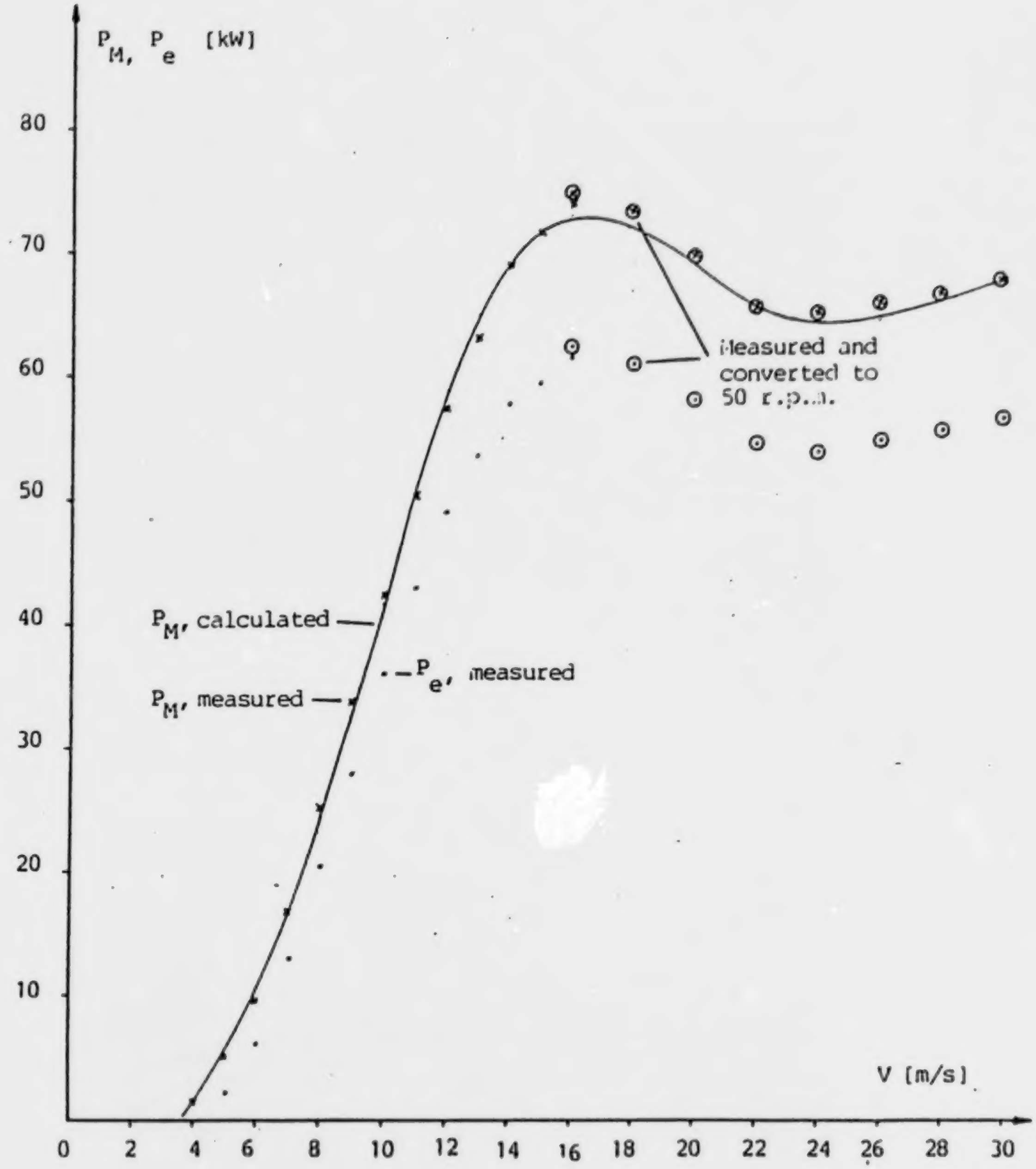


Figure: 7 Measured and calculated power curves.

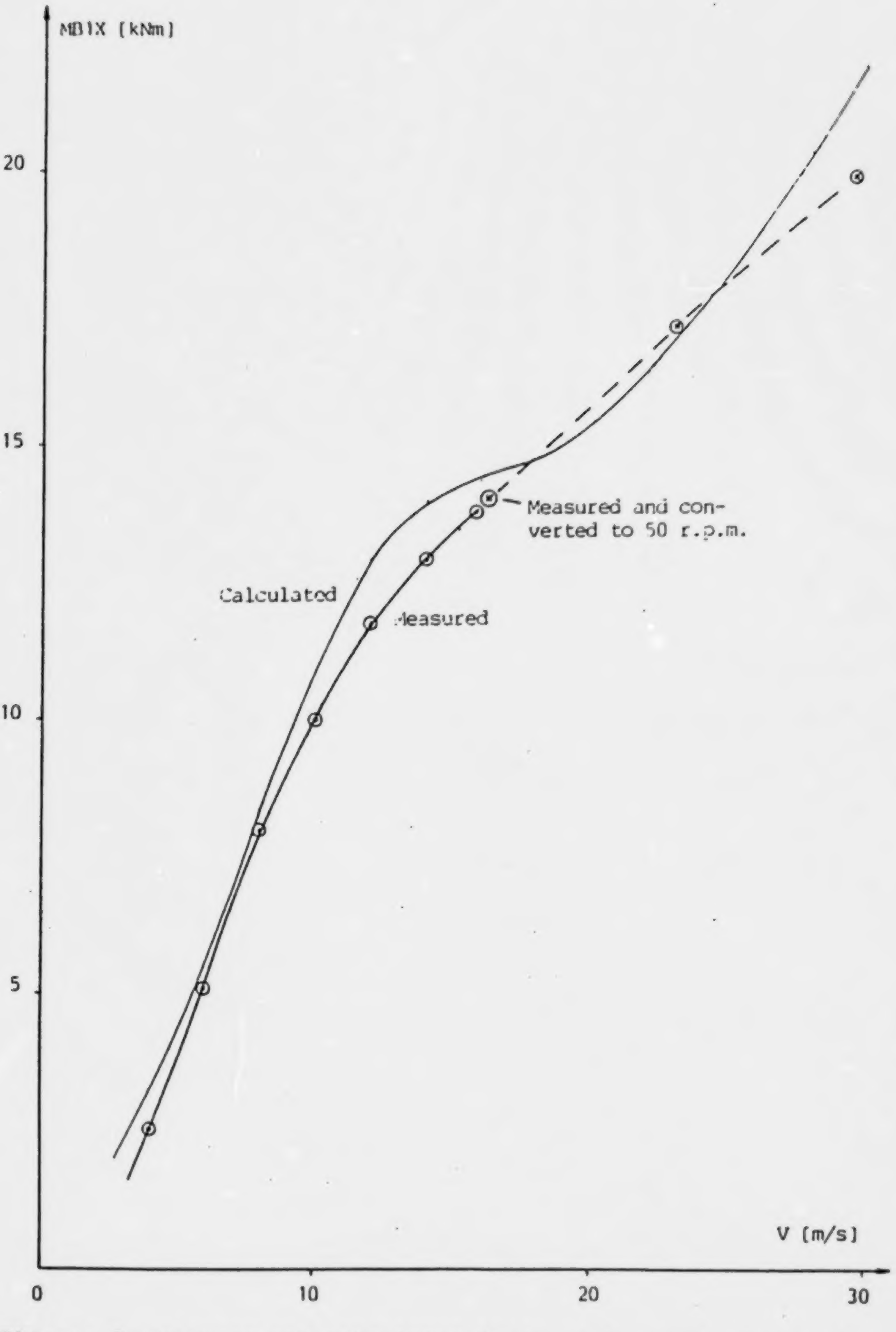


Figure: 8 Measured and calculated blade-root moment curves at r = 0.62 m.

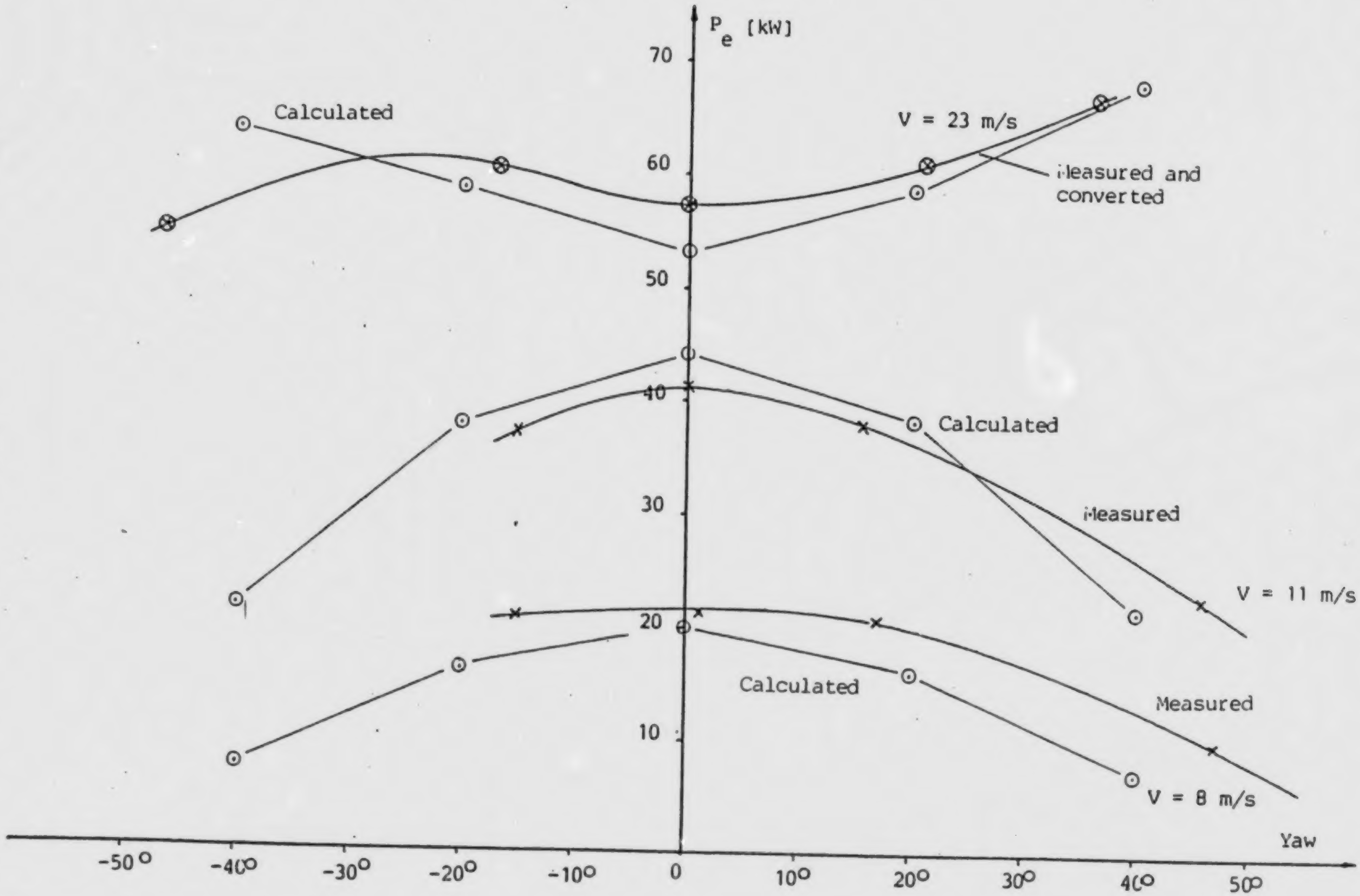


Figure: 9 Power output as function of yaw (measurements and calculations).

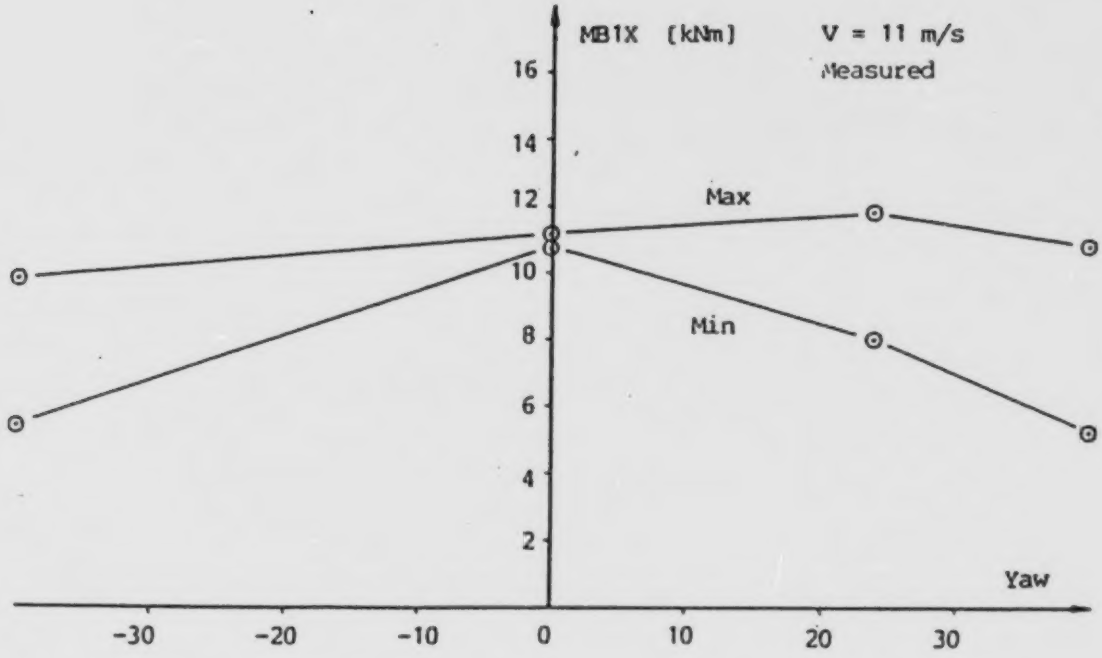


Figure: 10 Maximum and minimum for mean load during one revolution as function of yaw.

Figure: 11 SCOPE FOR IMPROVEMENTS:

HIGHER EFFICIENCY	∼25%
LIGHTER DESIGN	∼25%
MASS PRODUCTION	10-15%
LOWER INTEREST RATES	∼30%
HIGHER PRICES OF ELEC. (ENVIRONMENT)	∼30%
HIGHER FUEL PRICES	??

CONDITIONS:

PUBLIC SUPPORT FOR RESEARCH
— — — MARKET
FOR SOME TIME

LOW SPEED AERODYNAMICS STALL CONTROL METHODOLOGY

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National Aeronautical Establishment
National Research Council, Canada

Summary

Aerodynamic stall control is used in some of the most cost-effective and reliable horizontal and vertical axis wind turbines now in commercial production. It provides an alternative method to blade pitch control or other forms of variable geometry for the limitation and levelling of the power curve at high wind speeds, and undoubtedly leads to significant design simplification.

In this paper the basic principle of stall control is described, and some of its problems and their possible solutions are discussed.

1. Introduction

The term "stall control" refers to the control of the maximum power output of a wind turbine at high wind speeds by means of progressive aerodynamic stalling of the blades. In practice it is used only on turbines having constant rotor speed, independent of wind speed, but it is a feature designed into many of the most reliable and cost-effective horizontal and vertical axis wind turbines, (HAWT's and VAWT's) that are designed to be coupled to a.c. power systems. Stall control is not a new idea; it can be traced back in the literature for more than 50 years (Ref. 1). It was first used in the curved blade VAWT in 1973 at NRC.

The lower part of Figure 1 shows a typical wind turbine power curve of the stall-controlled type. All turbines designed for electric power output have a power curve something like this. Above a certain threshold, or cut-in wind speed power output at first rises gently and then more rapidly, in accordance with the fact that, theoretically, the available kinetic energy in the wind is proportional to the cube of the windspeed. However, if this increasingly rapid rise in power were allowed to continue indefinitely, the mechanical and electrical drive train, which is usually the most expensive part of the system anyway, would have to be made uneconomically large. The additional energy extracted at high wind speeds, which are relatively rare, would not be worth the cost. Instead, the power curve is made to level off so that the system can be allowed to operate at full rated power up to some selected cut-out wind speed. The common method of controlling maximum power, at least in HAWT's, is by means of various forms of automatic blade pitch control. This is a mechanical and control system complexity that has been avoided in the stall-controlled HAWT and VAWT . In fact in the case of the curved-blade Darrieus VAWT, it is not even a viable option for the designer.

The sketches in the upper part of Figure 1 are intended to explain, in an elementary way, how stall control works. The blade speed at any particular blade cross-section, is represented by the vector V_{BLADE} in the diagrams, and in constant speed

turbines it is independent of wind speed. In HAWT's the blade speed vector is always nearly at right angles to the wind speed vector V, and also in VAWT's as the blade passes across the front and rear faces of the rotor. The sketches show that, at low wind speeds the angle of attack of blade airfoils is generally low, at least for modern low-solidity turbines which develop their best efficiency when blade speed is high relative to wind speeds. As wind speed increases, the airfoil angle of attack eventually exceeds the angle for aerodynamic stall, and the flow separates from the low-pressure side of the blade. When this happens, the blade lift decreases or levels off and drag increases. The useful aerodynamic work done is provided by the component of lift which acts in the direction of blade motion, and thus power output ceases to increase. If the designer has done things right (or is lucky), the power curve will level off where he wants it, to match the rating of the drive train.

2. Why Use Stall Control?

In the design of a wind turbine system the designer is painfully aware of two difficult requirements: the need for high reliability and low cost. The difficulty is compounded by the fact that these two are usually conflicting; too much cost reduction leads to poor reliability and vice versa. In fact there is probably only one design guideline that helps meet both requirements at once: keep it simple. When one has examined the hundreds of incredible contraptions that have been invented to extract energy from the wind, one is forever astonished at the ability to ignore such an apparently obvious point.

The attractive feature of stall control of wind turbines is that it leads to significant simplification of system design. No blade pitch control, or other variable geometry is required in the rotor. For stall control to work, the rotor speed must be kept constant, or nearly so. This requirement leads to further simplification. In turbines that are coupled to a.c. networks, the common method is to use a squirrel-cage induction alternator as the electrical machine. This low-cost a.c. machine operates close to its synchronous speed, as determined by the frequency of the network, and works equally well as a motor (for starting) or as a generator. Moreover, operation at nearly constant speed greatly simplifies the problem of avoiding the structural resonances that have destroyed many wind turbines. Resonances are hard to avoid altogether, but those that occur at low rotor speeds are usually not serious if they can be traversed rapidly during starts or stops, and are not close to the normal operating speed.

One objection to stall control that is often raised is that average efficiency of the turbine system, and therefore its long-term energy production is compromised. This is true to some extent, but the penalty is not as great as is sometimes assumed. The argument is, of course, that a fixed-geometry rotor will be at its maximum aerodynamic efficiency at only one value of the ratio of wind speed to blade speed, and therefore, if blade speed is a constant, maximum efficiency will occur at only one wind speed. Ideally, if rotor speed were varied in proportion to windspeed, maximum efficiency could be attained over the whole operating range.

Let us consider an example. Figure 2 shows two power curves. One is the power curve for the stall-controlled VAWT that has been in operation on the Magdalen Islands for several years. Most of the curve was measured at the nominal operating speed of 36.6 rpm, but since wind speeds above about 15 m/s are too infrequent, even in this windy location, to ensure high accuracy of power measurements at the top end, the broken part of the curve is an extrapolation from measurements that were made at a reduced rotor speed of 29.4 rpm. In that case, wind speeds sufficiently high to level off the power were more frequent, but maximum power was much lower, so that the extrapolated curve in Figure 2 has been re-computed using standard speed scaling rules. The second curve in the figure is a cubic, which assumes that a hypothetical turbine is capable of maintaining maximum efficiency (the same as that of the Magdalen Islands turbine) at all wind speeds below maximum power. The maximum power was then levelled off at wind speeds above 12 m/s to match that of the Magdalen Islands turbine. The precise mechanism by means of which this power curve might be achieved in practice is of no concern here. Note that the graph refers to rotor shaft power.

From these two curves we can easily compute the expected long term mechanical energy output in each case, as a function of the average wind speed at the turbine site. This has been done, with the assumption that the distribution of windspeeds about the average value is given by the Rayleigh probability distribution. The result is summarized in Figure 3, in which it is seen that the energy penalty for stall control, in comparison with that of an idealized constant-efficiency version in the same rotor, is close to 10 per cent over a wide range of average wind speed. This is not negligible, but is a penalty that can be borne as long as the simplification of the overall turbine system (mechanical, structural and electrical) results in a cost reduction of more than 10 per cent. Obviously the designers of many of the most successful commercial turbines feel that this trade-off is in favour of the fixed geometry, stall-controlled, constant-speed concept. Examples would include the well-known family of Danish HAWT designs, as well as US and Canadian VAWTs.

3. Problems with Stall Control

In the design of wind turbines, as in most other engineering endeavours, there is no free lunch. Stall control has its problems, and needs more understanding of its behaviour if it is to become a fully reliable design feature. Some of these problems are as follows.

Stall control requires that the blade pitch be not only constant, but rather "flat" so that angles of attack will exceed the stalling angle at high windspeeds. In curved-blade VAWT's the blade pitch is effectively zero, since the blade chord is parallel to the direction of blade motion. For both HAWT's and VAWT's, this means that aerodynamic starting torque will be relatively weak. In some applications this could be a disadvantage, but with a.c. coupled systems using induction alternators, the low starting torque is in fact an advantage because starting is then under full electric system control and the brake torque when parked in high winds remains manageable.

Since the blades of a stall-controlled turbine rotor are of fixed geometry, they cannot be feathered when parked to minimize flatwise wind loads. Thus the blades of stall-controlled HAWT's are sometimes stiffened in the drag directon by additional tension struts which no doubt cause energy loss. This is not usually a serious problem in the Darrieus VAWT, owing to the stiffness inherent in the double-ended anchoring of the blades, although it is a design case that can not be ignored.

There are other aerodynamic problems. One of these is computational, and is the result of lack of complete understanding of rotor stall fundamentals. In some HAWT's it has been found that the power curve at high wind speeds rises to levels well above those predicted by some theories. The explanation probably has to do with three-dimensional spanwise flow in the blade boundary layers, resulting from centrifugal pressure gradients.

The same effect, the under-prediction of maximum power, occurs in Darrieus VAWT's, but the cause is believed to be different. In this case the discrepancy is usually attributed to the phenomenon known as dynamic stall. When the angle of attack of an airfoil is rapidly increased through what would have been its 'static' stall angle, aerodynamic stall is delayed and the airfoil lift momentarily rises to values that may be far above its maximum value under slowly varying conditions. In a VAWT, the blade angles of attack are continuously cycling between positive and negative values on the two sides of the turbine and when the amplitude reaches into the stalled region, dynamic stall effects become pronounced. The phenomenon has long been known in helicopter rotors, but basic experimentation is difficult.

Figure 4 shows once again the power curve for the Magdalen Islands turbine, but this time with the data points included.

Each of these represents a ten-minute average of many readings of both speed and power. The theoretical curves have been calculated by the version of momentum theory now most commonly used, called the double-multiple streamtube (DMST) theory, which is a descendant of the single streamtube (SST) theory originally described in Ref. 2. It is an adaptation of the venerable Betz-Glauert windmill momentum theory, coupled with strip theory, to the unique blade geomtery of the Darrieus rotor. In the DMST theory allowance is made for the difference in induced velocity over the rotor face, and from the upwind to the downwind face, and in the version used at NRC the computation of the dynamic stall effect is based on an empirical model developed for helicopters by R.E. Gormont of the Boeing-Vertol Company (Ref.3) but has been adjusted to match some data obtained on an oscillating airfoil model by R.H. Wickens at NRC (Ref. 4). The comparison between theory and measurement shown in Figure 4 is reasonably good, although by no means perfect, when the dynamic stall model is included, but the figure also suggests that theoretical dynamic stall effects are large.

Another potentially serious problem should be mentioned. This is the problem of blade structural fatigue that may be made more difficult by operation in deeply stalled conditions at high wind speeds. When an airfoil is stalled it is subject to high-frequency buffeting that may lead to local skin fatigue especially in HAWT's, which often have significantly higher blade speeds than VAWT's, but another aspect of the problem may be more serious in the latter type. The DMST theory can be used for the computation of detailed blade aerodynamic loading, as well as overall performance. One quantity that is of interest is the time history of the torque on each blade of a Darrieus VAWT. It is a complicated function of blade azimuth position, especially when cyclic stalling is occurring, but it can be broken down into its Fourier coefficients, or its separate harmonic amplitudes. When this is done for the Magdalen Islands turbine at 36.6 rpm, the theoretical result is as shown in Figure 5. The graph shows the single-blade torque amplitude about the rotor axis, as a function of windspeed. The "zero-th" harmonic is actually the mean value of the torque and it will be noticed that it is the same shape as the calculated power curve in Figure 4. (At constant rotational speed, mean torque is proportional to power). The actual torque function is made up of the mean torque and of harmonics that have frequencies equal to integer multiples of rotational speed.

The reason why the one-blade torque is of interest here is that it is known (both from measurements and theoretical structural dynamic calculations) that the largest stresses in Darrieus rotors tend to result from lead-lag bending of the blades, and this is excited by the same aerodynamic loads that produce shaft torque. For reasons that are outside the scope of this paper, these cyclic bending stresses are mainly induced by the odd harmonics of blade loads (1st, 3rd, etc.), whereas on a two-bladed rotor (the most common configuration) the total shaft torque "ripple" contains only even blade harmonics (mainly the '2-per-rev' component). Beyond about the 5th harmonic, these separate components tend to be small, and are not shown in Figure 5. Bearing in mind that the Magdalen Islands rotor begins to stall at winds speeds above about 10-12 m/s, the figure shows the rapid growth of the first two odd harmonics under deeply stalled conditions. Experimental strain gauge measurements confirm that, although overall stresses are generally low, the cyclic components (that can produce fatigue damage) do grow rapidly with wind speed in this range. In fact it happens that the Magdalen Islands turbine has one of its rotor natural frequencies not far from 3 times rotor speed, and this amplifies the 3-per-rev stress component. Apart from the obvious need to design the rotor structure to avoid resonances as far as possible, it is also advisable to give careful consideration to the choice of cut-out wind speed in stall-controlled turbines. A relatively small reduction may have little effect on energy production, but a large effect on fatigue life.

4. Conclusion

Stall control to limit maximum power output of horizontal and vertical axis wind turbine rotors has attractive advantages in simplification of system design, and is a feature of some of the most successful commercial products.

Although its main features are qualitatively understood, sufficiently for most design purposes, there are still some basic aerodynamic puzzles requiring further research. Stall control also has certain problems that require careful consideration at the design stage. These include uncertainties in the accurate prediction of maximum power output and possible problems with blade fatigue due to operation in deeply stalled conditions.

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Q. Jack, I wonder if you care to comment on the difficulty of predicting the response of the rotor from the point of view that even though the forcing function is understood, the modal shapes and the phase differences that come about, because of the number of modes of vibration of the rotor in relation to the forcing function, make it difficult to determine at a given tip speed ratio, exactly what the response of the rotor is going to be?

A. I don't have that much comment, Lawrence. I'm not a structural dynamics expert and you'll notice I carefully stuck to aerodynamics in the paper, but you are quite right, the structural dynamics characteristics of these rotors are extremely complicated, and I realize also that something I said was a little oversimplified. In pointing out, for example, the one and three times per rev curves, you'll notice they really do rise theoretically much more steeply than I think the experimental curves of stress that you showed this morning, do. And I can't explain that.

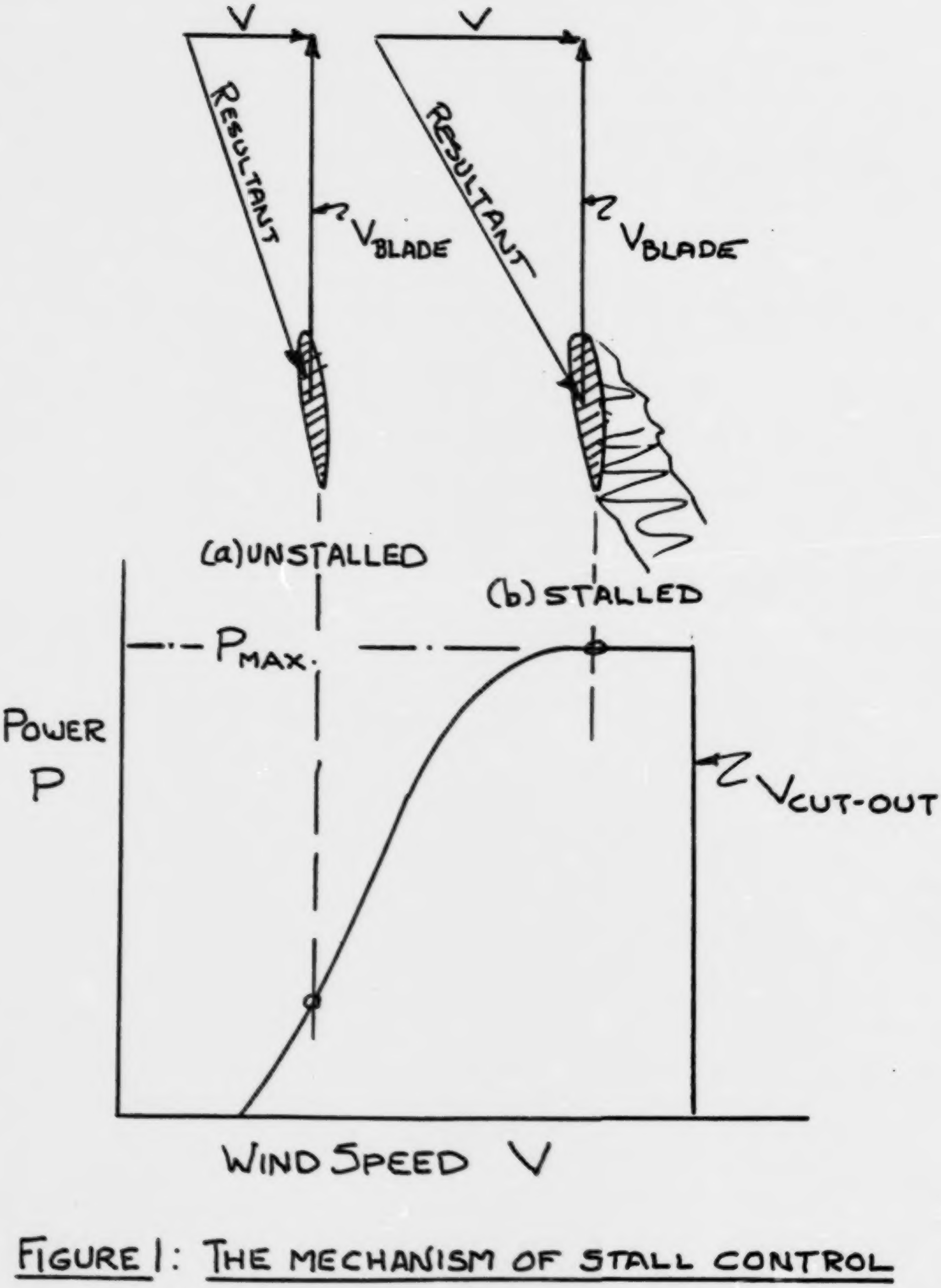
V
RESULTANT
V_{BLADE}
V
RESULTANT
V_{BLADE}
(a) UNSTALLED
(b) STALLED
P_{MAX}
POWER
P
$V_{CUT-OUT}$
WIND SPEED V

FIGURE 1: THE MECHANISM OF STALL CONTROL

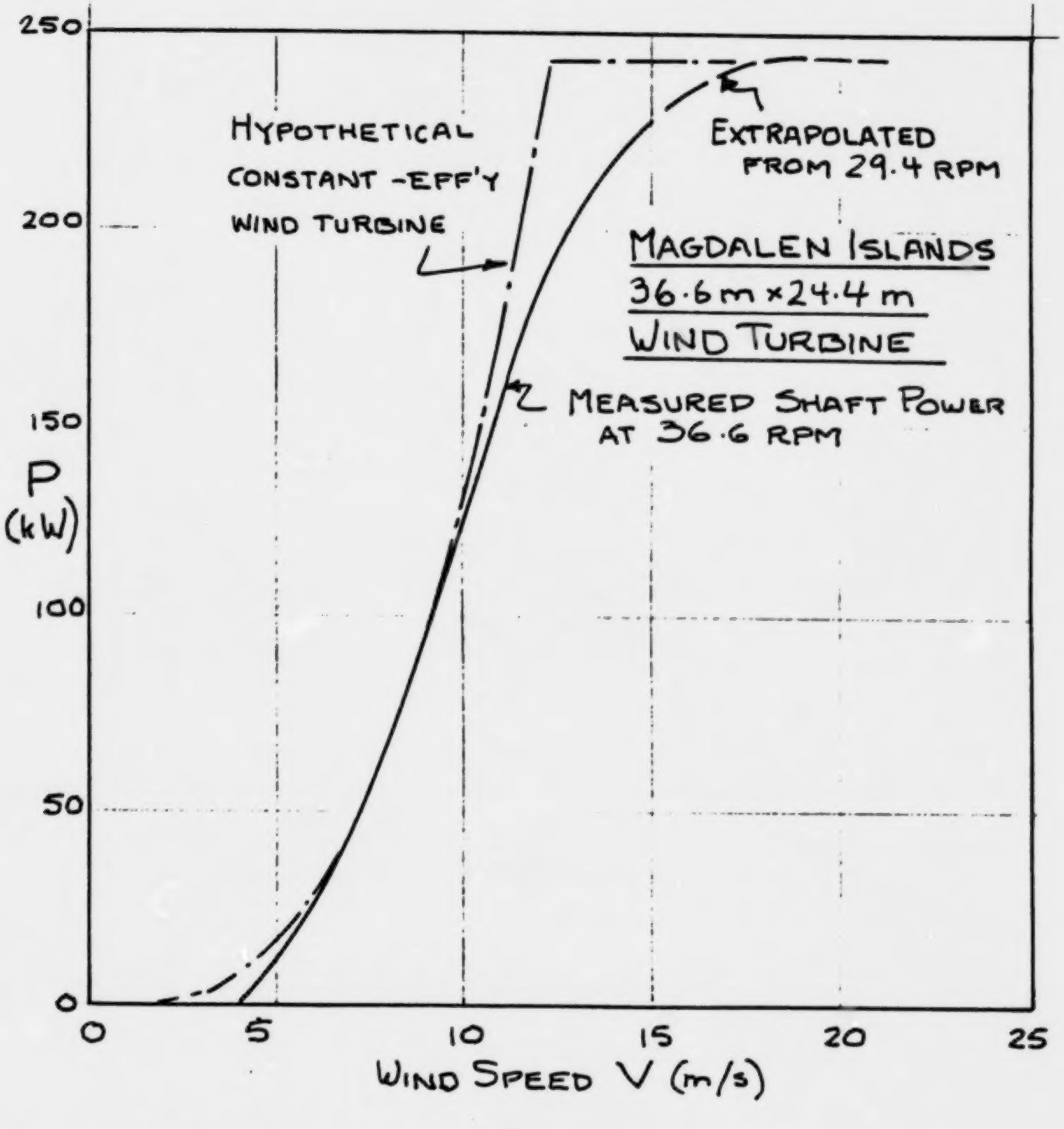

Figure 2: Comparison between stall-controlled and constant-efficiency performance for equal values of P_{MAX}.

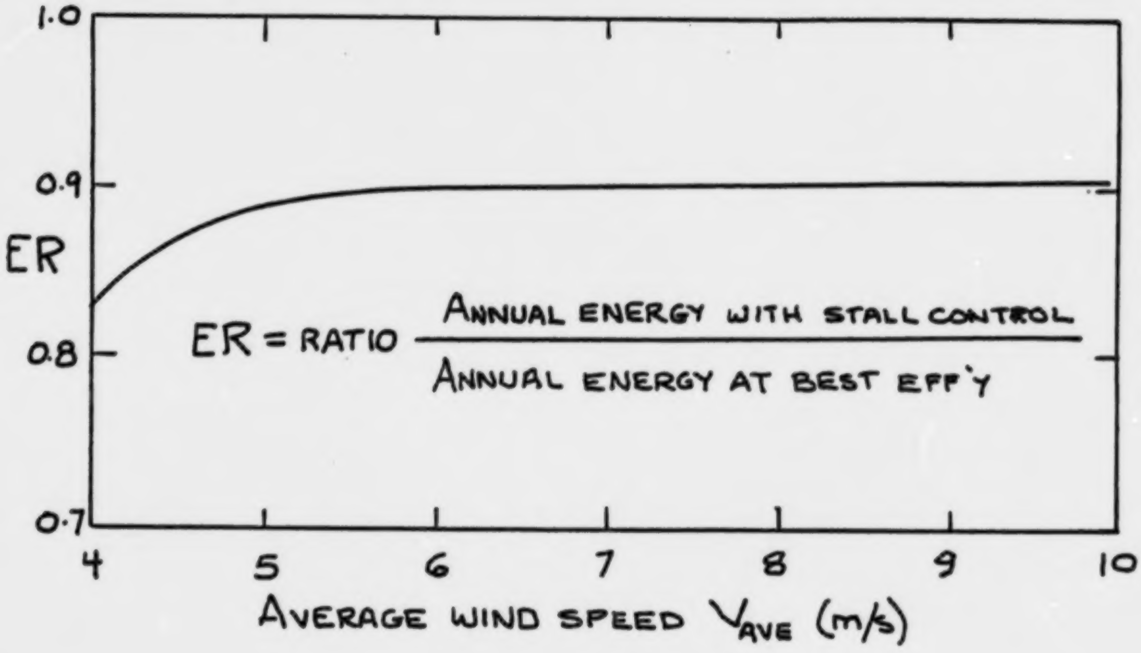

FIGURE 3: ENERGY PENALTY FOR STALL CONTROL

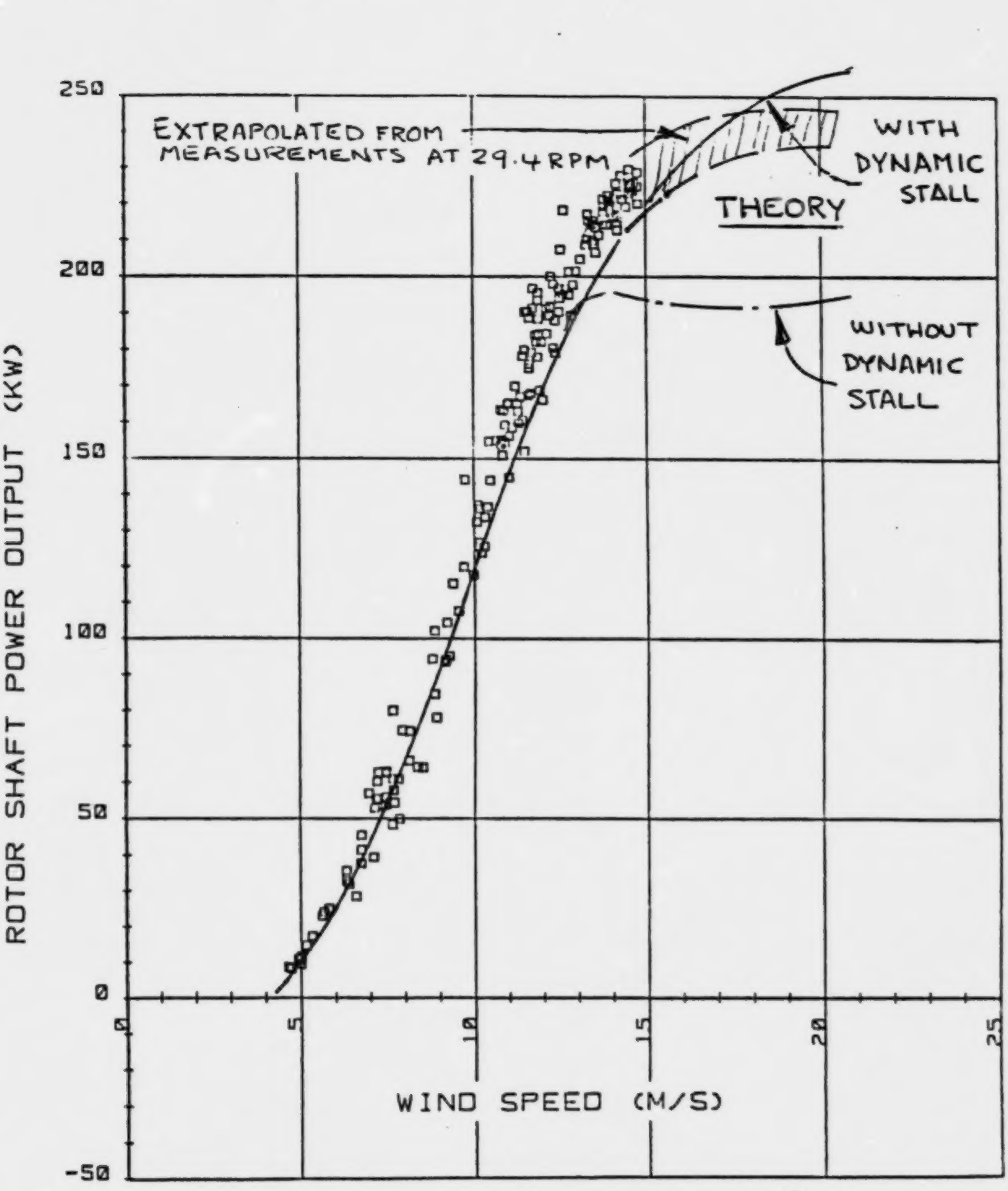

FIGURE 4: MAGDALEN ISLANDS WIND TURBINE - COMPARISON OF MEASURED AND THEORETICAL PERFORMANCE AT 36.6 RPM.

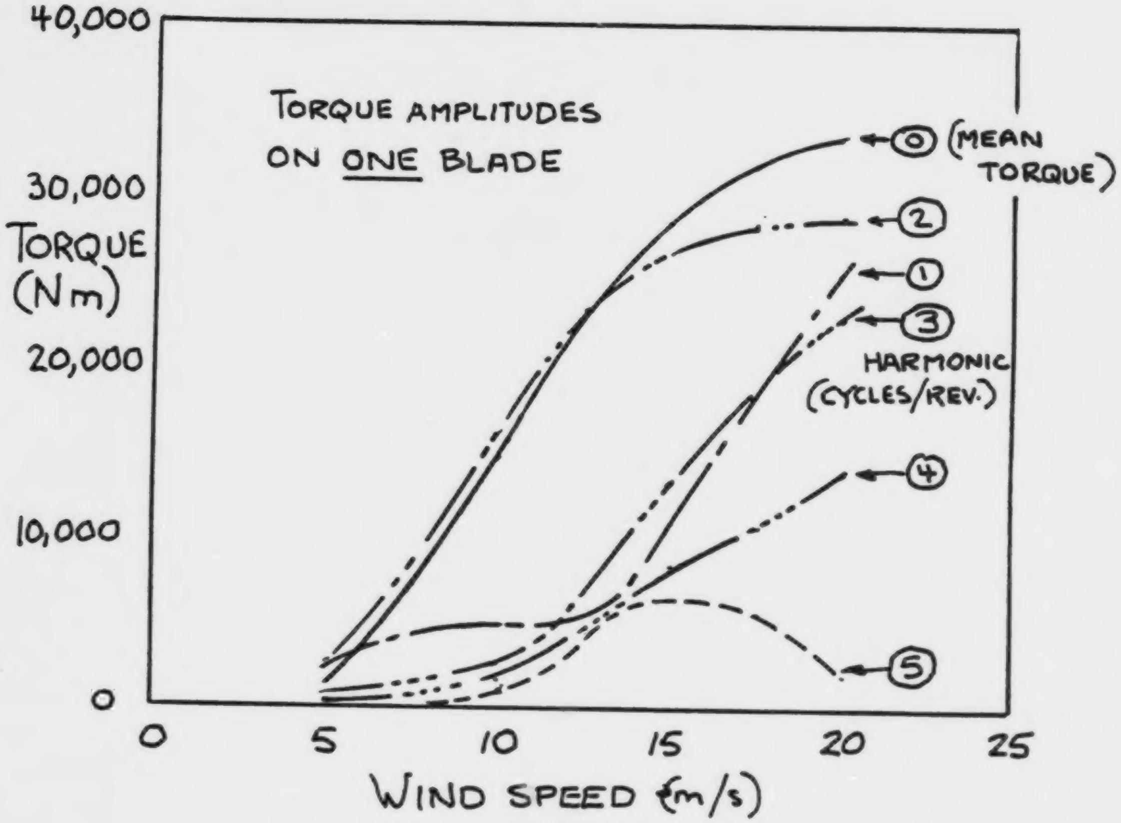

FIGURE 5: MAGDALEN ISLANDS WIND TURBINE - CALCULATED AMPLITUDES OF TORQUE HARMONICS ON EACH BLADE

NUMERICAL MODELLING OF WIND-FLOW MODIFICATIONS BY COMPLEX TOPOGRAPHY: COMPARISON OF MODEL RESULTS WITH ASKERVEIN 1983 DATA

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J.R. Salmon

SUMMARY

A simple, linearized model of boundary-layer flow over low hills and other terrain features is described together with applications to Askervein, South Uist, Scotland.

The model (designated MS3DJH/3) is based on a division of the flow into an outer, inviscid, irrotational layer and an inner turbulent layer. Length scales and advection velocities are wavenumber-dependent and inner- and outer-layer solutions are blended. The use of Fourier transforms in the horizontal coordinates allows for analytic solutions in the vertical coordinate. The transforms and solutions are evaluated numerically, but the computer time required is at least two orders of magnitude less than that required for finite-difference models with the same resolution.

Results from the model are compared with data taken during the International Energy Agency experiment at Askervein in September/October 1983. The roughness was essentially uniform and the flow neutrally stratified. Results are presented for vertical profiles of normalized wind speed up to 150 m above the hill-top, horizontal cross-sections of normalized wind speed and contour maps of normalized wind speed and wind direction.

1. INTRODUCTION

Askervein, located on the island of South Uist in the Outer Hebrides of Scotland, was the site of field experiments in September-October 1982 and 1983 (Fig. 1). These experiments were conducted as part of Task VI of the International Energy Agency (IEA) Program of Research and Development on WECS, the objective of which was to collect data suitable for the verification of physical (wind tunnel) and mathematical models. Groups representing five countries (Canada, Denmark, Federal Republic of Germany, New Zealand, United Kingdom) participated in the field experiments. Reports on the data collected have been prepared (3, 4).

2. BOUNDARY-LAYER MODEL

The boundary-layer model, designated MS3DJH/3, is based on the two-dimensional theory of (1) as modified and extended to three dimensions by (2) and further modified to incorporate wavenumber-dependent scaling and a blending of inner- and outer-layer solutions by (5). A summary of the characteristics of the model is given in Fig. 2 and a flow chart with a list of definitions appears as Fig. 3.

3. SAMPLE MODEL RESULTS COMPARED WITH DATA

In Fig. 4 are plotted vertical profiles of normalized wind speed (wind speed normalized by speed in the undisturbed upwind flow at the same height above ground). The model results are represented by curves and the data are depicted by a mean value and, where appropriate, a standard deviation. Fig. 4a is for a case with upstream wind direction 210°. Field data were obtained from cup anemometers mounted on 50-m towers at the hilltop and upwind reference sites (HT, RS). (See Fig. 1). Fig. 4b displays composite profiles from the same towers and from TALA kite flights at a location mid-way between the "centre point" of the hill (CP) and HT. The two sets of data overlap in the range 40-48 m above ground where they show a difference in normalized speed of order 0.1

due to their horizontal displacement of about 200 m. Upstream wind direction was approximately 180°. MS3DJH/3 results for the two locations are shown for comparison. In both Figs. 4a and 4b the main discrepancy between the model results and the data is at low levels (within 3-25 m of the ground). Among possible explanations for this discrepancy are: (i) a non-logarithmic upstream wind profile, (ii) a small-scale terrain feature near HT not resolved by the 25-m model grid, (iii) variable surface roughness effects and (iv) cup-anemometer overspeeding at low levels. The most likely explanation is (i) which was observed to a greater or lesser degree in the data sets examined; (ii) and (iii) are hypothetical and could cause low-level model overestimation as easily as underestimation. Two additional possibilities are simply that the linear theory upon which the model is based is being stretched too far in the present application or that the assumed form of turbulence closure is inadequate.

Fig. 5 displays normalized wind speed along horizontal cross-sections of length 2 km. The dashed lines indicate the terrain elevation. The point HT is about 116 m above the level of the surrounding flat terrain which was assumed to be 10 m above mean sea level. Results are shown for two upstream wind directions and for the three cross-sections indicated in Fig. 1. Agreement between the model results (solid curves) and the data is excellent on the upwind slopes (left side of Figs. 5a,b,d,e), near HT and CP (Figs. 5a-f) and along the ridge line (Figs. 5c,f). The main differences between model results and data tend to be on the downwind side of the hill, particularly on the ASW-ANE cross-sections (Figs. 5a, d) and on the AASW-AANE cross-section with upstream flow nearly perpendicular to the ridge line (Fig. 5e).

4. SAMPLE CONTOUR MAPS PRODUCED FROM MODEL RESULTS

Fig. 6a shows a contour map of the central portion (64 x 64 grid points as indicated by tick marks on the perimeter) of the 256 x 256 grid of terrain elevation data used as input to the MS3DJH/3 model. The grid data were obtained from Fig. 1. All of the diagrams in Fig. 6 are oriented so that the upstream wind direction (180°) is from the left. Results of normalized wind speed and wind direction relative to the upstream direction (positive counterclockwise; negative values are indicated by dashed lines) are shown in Figs. 6b-e for two heights above ground (10 m and 20 m). Maxima in normalized wind speed occur in the vicinity of HT slightly upwind of the ridge line and range from about 1.6 at 10 m to 1.5 at 20 m. Wind direction deviations are positive (tending to be deflected parallel to the ridge line) upwind of the ridge with maximum values of 8-10°. The flow then crosses the ridge at negative angles of 10-13° (more perpendicular to the ridge line than the upstream flow) and then turns back (positive) at angles of 7-9°.

The results shown in Fig. 6 are for the same case (180°) as was presented (for 10 m) in Figs. 5d-f where the agreement with data is excellent except on the leeward side of the hill. Despite the fact that there is not sufficient data with which to draw contour maps, we have considerable confidence in the accuracy of these model-produced wind-speed contour maps, except to the right of the ridge line where the model overestimates.

A preliminary comparison of wind direction model results and data suggests that the trend shown for this particular flow orientation (backing of the flow on the upwind slope, veering as it passes over the ridge line and then backing again on the lee side) is correct but that the magnitudes of the model results may be of order 5-10° low.

5. OUTLINE OF FUTURE WORK

The MS3DJH/3 model has been modified (6) to incorporate variable surface roughness. This is probably not an important factor in the case of Askervein (though this will be investigated) but will be significant for other areas. In order to improve the low-level accuracy of the MS3DJH/3 model, it is planned to replace the present assumption of an upstream logarithmic wind profile with an arbitrary profile. Work has also begun on incorporating stratified flow. Longer-term plans are to develop a new model, based on experience gained with MS3DJH/3 but including an improved turbulence closure scheme and allowing for non-linear effects.

ACKNOWLEDGEMENTS

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Q. Just a small point of clarification. In the profile plots you showed, the log-linear plots, the definition again of the speedup factor was: 'the ratio of the local windspeed at wherever the measurement is made at whatever height, to the speed far upstream on the flat at the same height above local ground'?

A. Yes that's right. Except on one of the plots where the tala-kite data was and that's referenced, well, I'm actually not absolutely sure, it may be referenced to the speed at 50 meters on the tower.

Q. I just want to ask about what use you see for the model. Are the inputs for this going to be simple enough that wind farm developers could afford to use it before siting their wind turbines, or are you envisaging it's use to develop simpler models which wind farm developers can use? What's the cost of the input and what is the benefit?

A. (Salmon) I didn't say it was user unfriendly to scare anybody away. I said it was user unfriendly in that it's a complex model and needs a fairly large computer, at the moment, to run on. The inputs are very simple. There's two inputs at the moment. There's the aerodynamic roughness, the Z_0 and there's the

wind direction. Other than that everything else is specified.

Essentially the other input is the contour or the topography, but that's pretty well fixed. You put in a contour map and that's easy to do. You use any standard contouring routines to give it data. So, yes, in that sense once you know how to use it, it's extremely simple. You can typically... What a wind farm developer might want to do is run it for 20 degree increments all the way around the compass rose and get a plot of windspeeds on top of a hill as a function of direction. By going to the nearest metereological station, cross co-relating that with the measured wind rose, he can get an idea of what sort of power-up factors he would get. That is, more power because of the speed-up effect on top of the hill. But yes it's easy to use. Peter...

A. (Taylor) I was going to comment on that. We have been applying the model to a number of sites on the Magdelen Islands over the last few months. This was our first attempt really, to use the model as a wind prospecting tool. It will take us a while to iron all the bugs out. But, basically, it seems to work fairly well, as long as you're concerned with putting in a significant amount of capacity. If you're interested in 50 kilowatt machines then you try to use guidelines rather than this model.

Q. Are there downstream or downside disadvantages of the sped-up flow on a hill in terms of increased roughness in the flow or turbulence or things which might bother the designer from say a structural point of view?

A. I think so. Some of the data from Askervein that we've started to look at shows wind direction reversals in the lee of the hill, that sort of problem. I don't think you'd want to put a wind turbine in the lee of a hill.

Q. And in the area on the oncoming face of the hill where you still get significant speed up, there is not a concommitant increase in roughness in the flow that would worry the structural aspects??

A. No, as a matter of fact, I think the turbulence levels go down on the upwind face of the hill.

A. (Teunissen) The turbulence we've been finding, Mark, goes up in the bottom four or five meters, certainly on this hill. All three components of turbulence go up there. Above that they either stay the same depending on the component, or some of them decrease slightly. So, in other words, you'll have $\bar{U}$ going way up, by perhaps a factor of two. Sigma above five meters will either be constant or perhaps even down a little bit. So, your intensity could be down by a factor of two. In fact, you're doing okay in terms of turbulence. For example, if you are talking about gust factor loading something on top, your gust factor doesn't go up nearly as much as your mean speed does. You may have a 100 per cent increase in mean speed, but on total gust you might only be up 40 or 50 per cent. So it looks promising in the sense of not being as tough turbulence-wise as it might be in terms of mean flow.

Q. It might not be a free lunch but a very cheap lunch!

ASKERVEIN, South Uist, Scotland

Measurement Locations & Model Cross-Section Lines

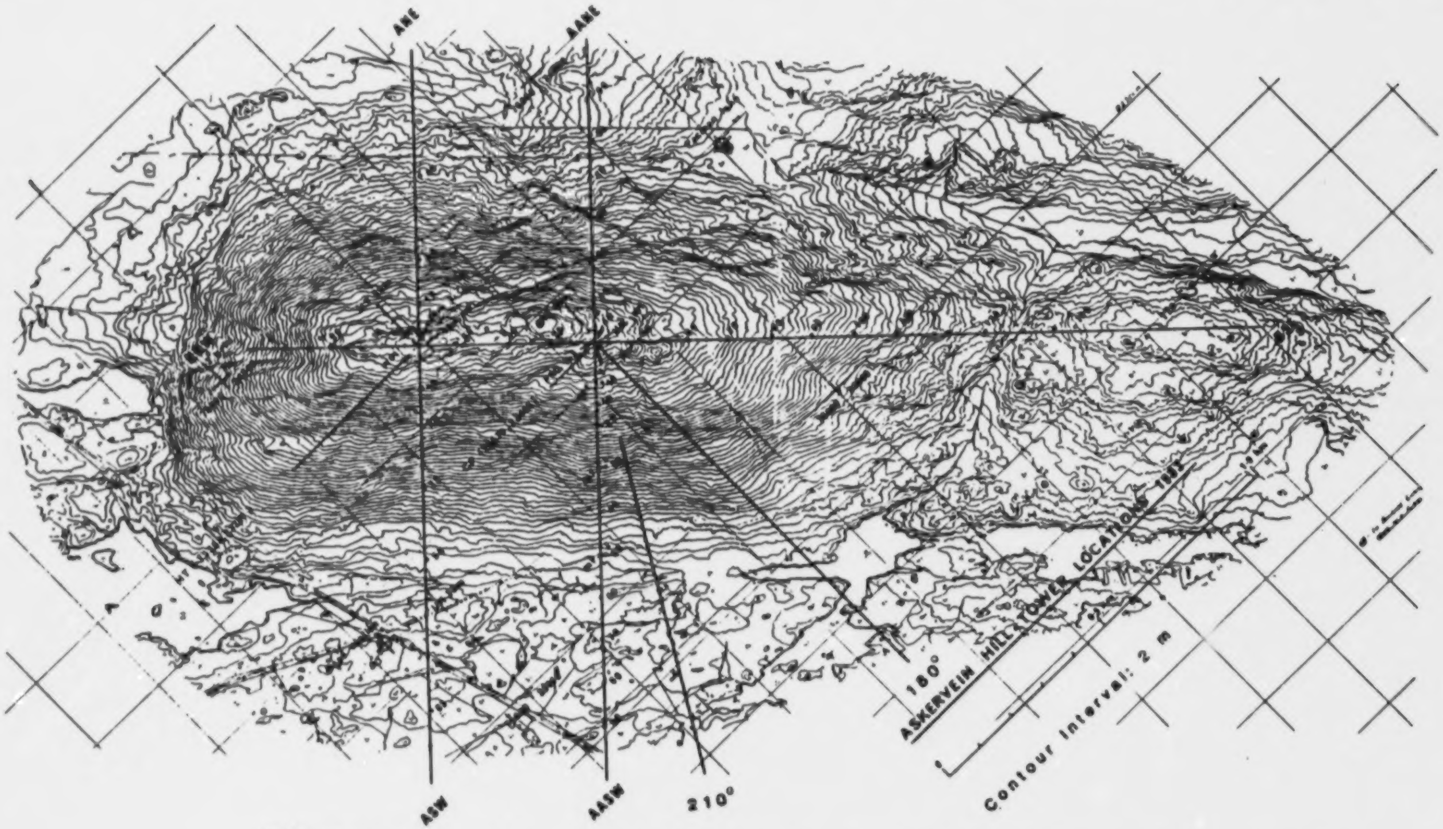

ANE
AANE
ASW
AASW
210°
180°
ASKERVEIN HILLTOWER LOCATIONS
Contour Interval: 2 m

Figure: 1

Contour map of Askervein, South Uist, Outer Hebrides, Scotland. Contour intervals is 2 m. Experimental data was made on towers located along lines ASW-ANE, AASW-AANE, BNW-BSE. The upwind reference site (RS) lies off the map approximately 30 km to the south-southwest of the hilltop site (HT). The "centre point" of the hill (CP) lies on the BNW-BSE line approximately 400 m from HT. The background grid of 2-km squares is from the British Ordnance Survey. Two upstream wind directions, relative to the grid, are included for reference to model results and data periods.

CHARACTERISTICS OF THE MS3DJH/3 MODEL

Fiqure: 2

The MS3DJH/3 Model: Characteristics, Advantages and Limiting Factors.

NEUTRALLY-STRATIFIED BOUNDARY-LAYER FLOW

THREE-DIMENSIONAL	**LOGARITHMIC UPSTREAM WIND PROFILE**
LINEARIZED	**MIXING-LENGTH TURBULENCE CLOSURE**

ANALYTICALLY-SPECIFIED OR REAL TERRAIN

TWO-LAYER MODEL :
Outer layer is inviscid and irrotational.
Inner layer involves a balance between acceleration, pressure and turbulent shear stress terms, the pressure being obtained from the outer-layer solution.

FOURIER TRANSFORMATION:
Main calculations are done in Fourier mode as functions of downwind & crosswind wavenumbers (k,m).

FAST-FOURIER-TRANSFORM (FFT)
used to convert dimensionless terrain heights prior to main calculations.

INVERSE FFT
used to convert pressure, shear stress & velocity perturbations to real space mode after main calculations.

LENGTH AND ADVECTION VELOCITY SCALES IN BOTH INNER- AND OUTER-LAYERS ARE WAVENUMBER-DEPENDENT.

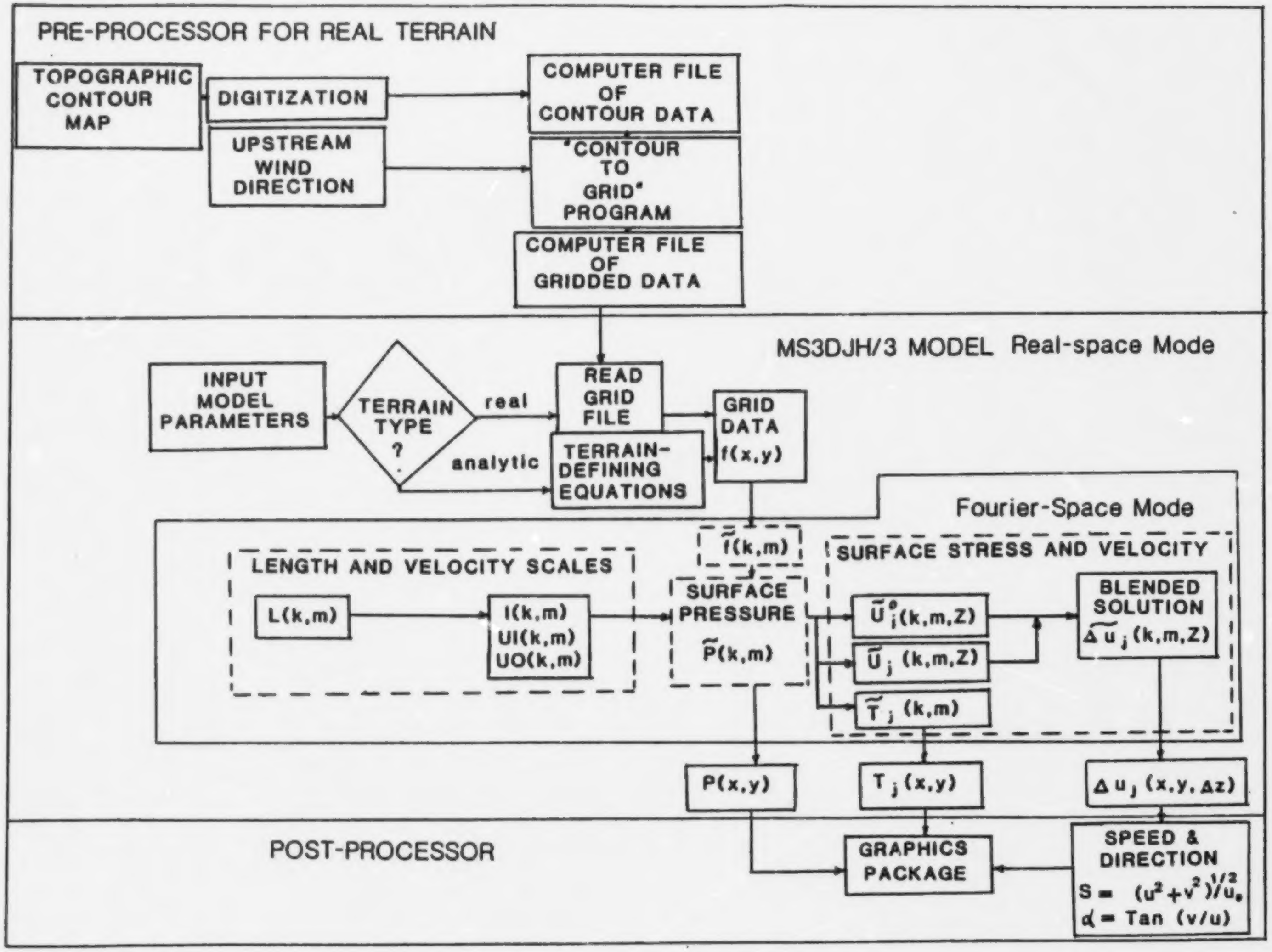
ANALYTIC SOLUTIONS IN VERTICAL COORDINATE

ADVANTAGES:

1) High spatial resolution in all three dimensions
   (Typically horizontal grid spacing of about 25 m for hill of horizontal scale 1 km. Any desired resolution in vertical due to analytic nature of solutions).
2) Very rapid calculations
   (Typically 40 s CPU time on CRAY-1S computer for 256 x 256 horizontal grid points and 4 vertical levels).
3) Physically realistic results for velocity

LIMITING FACTORS:

1) Neutral Stratification
2) Uniform roughness
3) "Gentle" slopes
4) Mixing-length closure
5) Logarithmic Upstream Profile


PRE-PROCESSOR FOR REAL TERRAIN
TOPOGRAPHIC CONTOUR MAP
DIGITIZATION
UPSTREAM WIND DIRECTION
COMPUTER FILE OF CONTOUR DATA
'CONTOUR TO GRID' PROGRAM
COMPUTER FILE OF GRIDDED DATA
MS3DJH/3 MODEL Real-space Mode
INPUT MODEL PARAMETERS
TERRAIN TYPE ?
real
analytic
READ GRID FILE
TERRAIN-DEFINING EQUATIONS
GRID DATA f(x,y)
Fourier-Space Mode
LENGTH AND VELOCITY SCALES
L(k,m)
l(k,m)
UI(k,m)
UO(k,m)
f̃(k,m)
SURFACE PRESSURE
P̃(k,m)
SURFACE STRESS AND VELOCITY
Ũ°ᵢ(k,m,Z)
Ũⱼ (k,m,Z)
T̃ⱼ (k,m)
BLENDED SOLUTION
Δũⱼ (k,m,Z)
P(x,y)
Tⱼ (x,y)
Δ uⱼ (x,y, Δz)
POST-PROCESSOR
GRAPHICS PACKAGE
SPEED & DIRECTION
S = (u² + v²)^1/2 / u*
α = Tan (v/u)

FLOW CHART
FOR
MS3DJH/3 MODEL
AND ITS
PRE- AND POST-
PROCESSORS

Figure: 3 (a)

DEFINITIONS

REAL SPACE COORDINATES

x = UPSTREAM WIND DIRECTION

y = CROSSWIND DIRECTION

Δz = HEIGHT ABOVE GROUND

FOURIER SPACE COORDINATES

k = WAVENUMBER IN x-DIRECTION

m = WAVENUMBER IN y-DIRECTION

Z = DIMENSIONLESS VERTICAL COORDINATE

WAVENUMBER-DEPENDENT SCALES

L = HORIZONTAL LENGTH SCALE
= OUTER LAYER LENGTH SCALE

l = INNER LAYER LENGTH SCALE

UO = OUTER LAYER VELOCITY SCALE

UI = INNER LAYER VELOCITY SCALE

DIMENSIONLESS PERTURBATION VARIABLES

f = TERRAIN HEIGHT

P = SURFACE PRESSURE

U_j^o = OUTER-LAYER VELOCITY

U_j = INNER-LAYER VELOCITY

T_j = SURFACE SHEAR STRESS

Δu_j = BLENDED VELOCITY

$j = 1, 2$

$\tilde{(\ )}$ = FOURIER COEFFICIENT

$u_0(\Delta z)$ = UPSTREAM WINDSPEED PROFILE

Figure: 3(b) Flow Chart for the MS3DJH/3 Model and its Pre- and Post-Processors, including a definition of variables.

NORMALIZED WIND SPEED vs. HEIGHT ABOVE GROUND

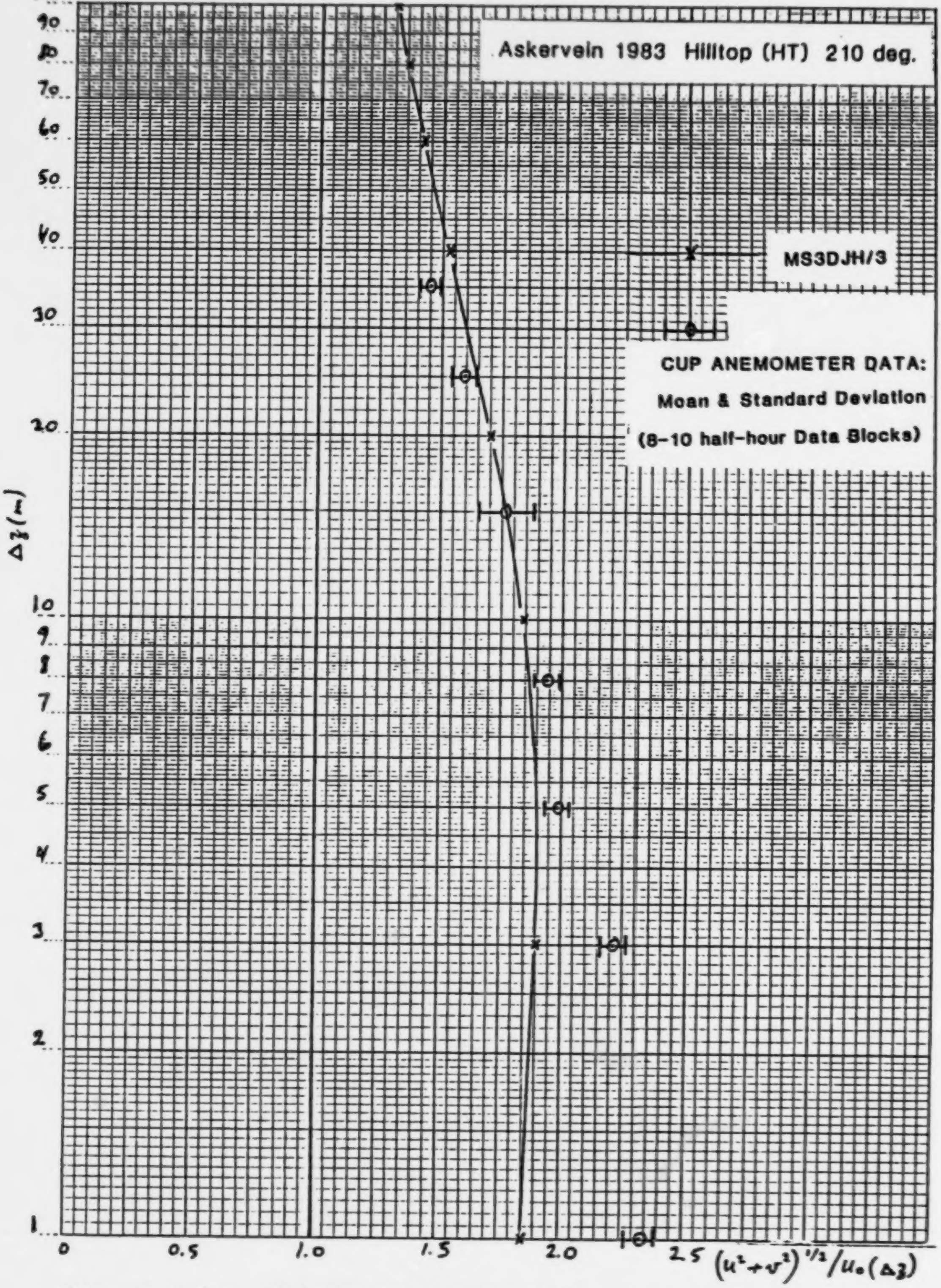
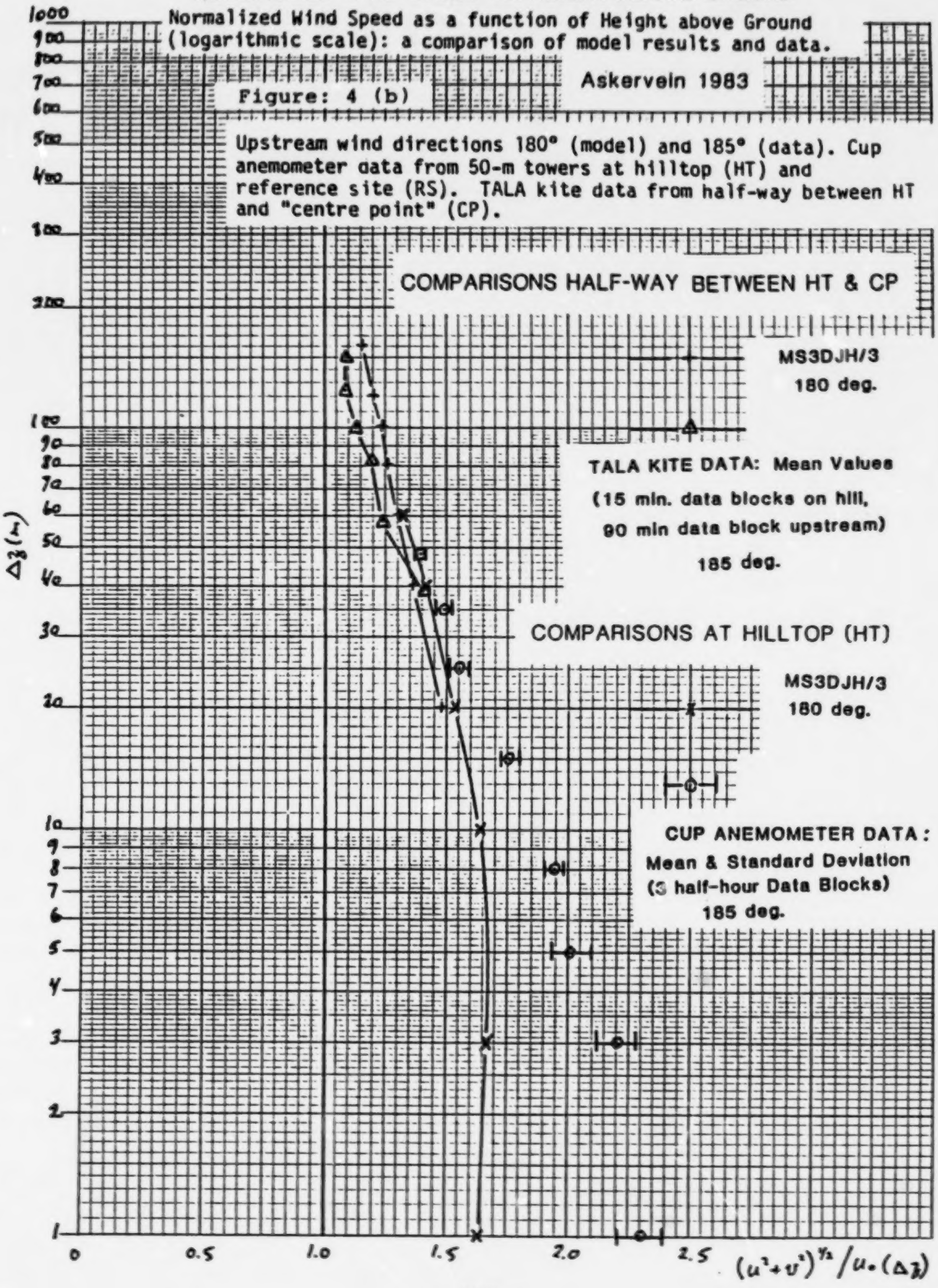


Figure: 4 (a) Upstream wind direction 210°. Cup anemometer data from 50-m towers at hilltop (HT) and reference site (RS).

NORMALIZED WIND SPEED vs. HEIGHT ABOVE GROUND



Normalized Wind Speed as a function of Height above Ground (logarithmic scale): a comparison of model results and data.

Askervein 1983

Figure: 4 (b)

Upstream wind directions 180° (model) and 185° (data). Cup anemometer data from 50-m towers at hilltop (HT) and reference site (RS). TALA kite data from half-way between HT and "centre point" (CP).

Horizontal Cross-Sections of Normalized Wind Speed at 10 m above ground: a comparison of model results and data. Each cross-section is 2 km in length. Solid curves are model results. Dashed curves are terrain elevations above a reference level typical of the flat terrain upstream (10 m above mean sea level).

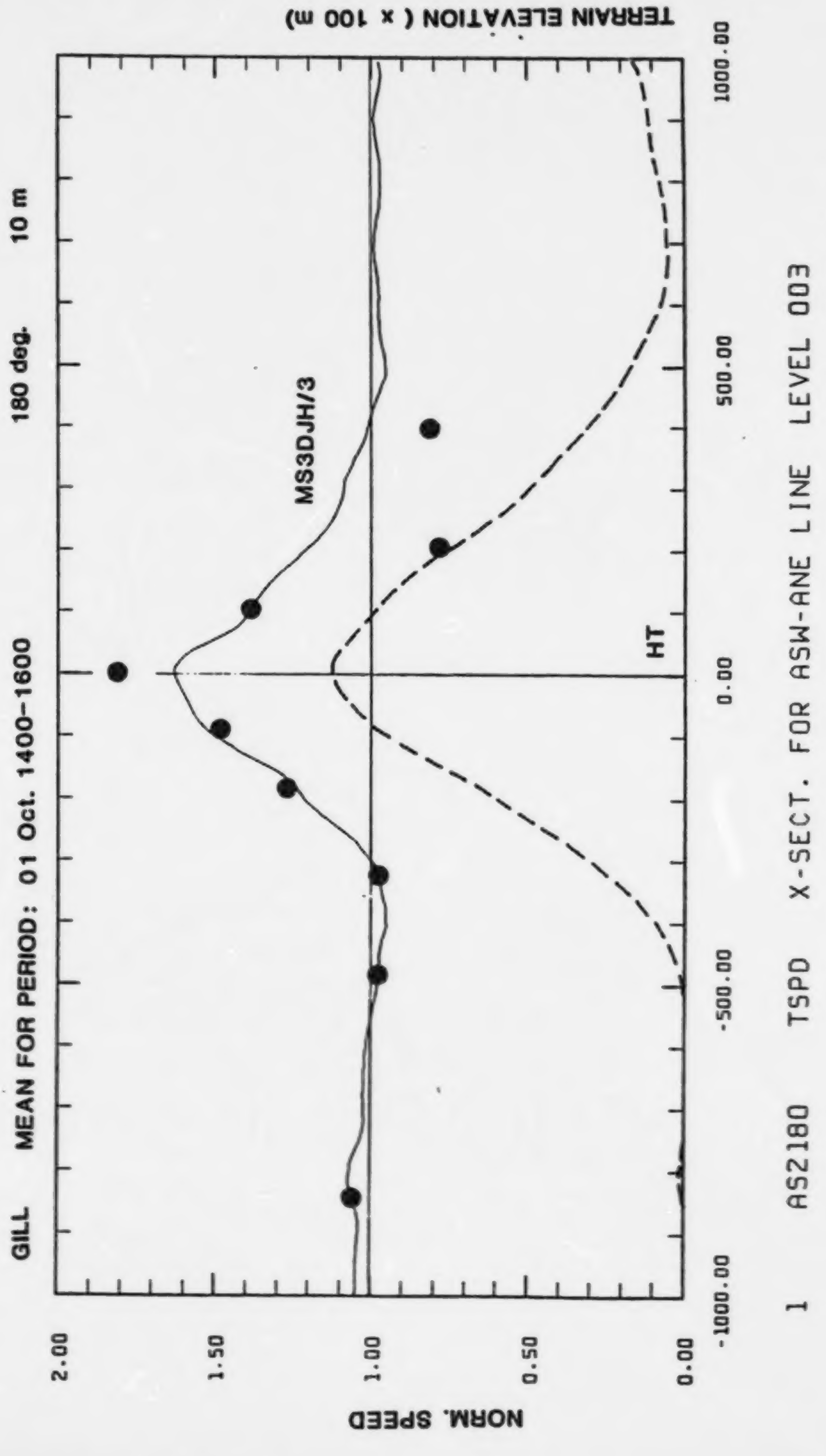


Figure: 5 (a) Upstream wind direction 180°. ASW-ANE cross-section.

Figure: 5 (b) Upstream wind direction 180°. AASW-AANE cross-section.

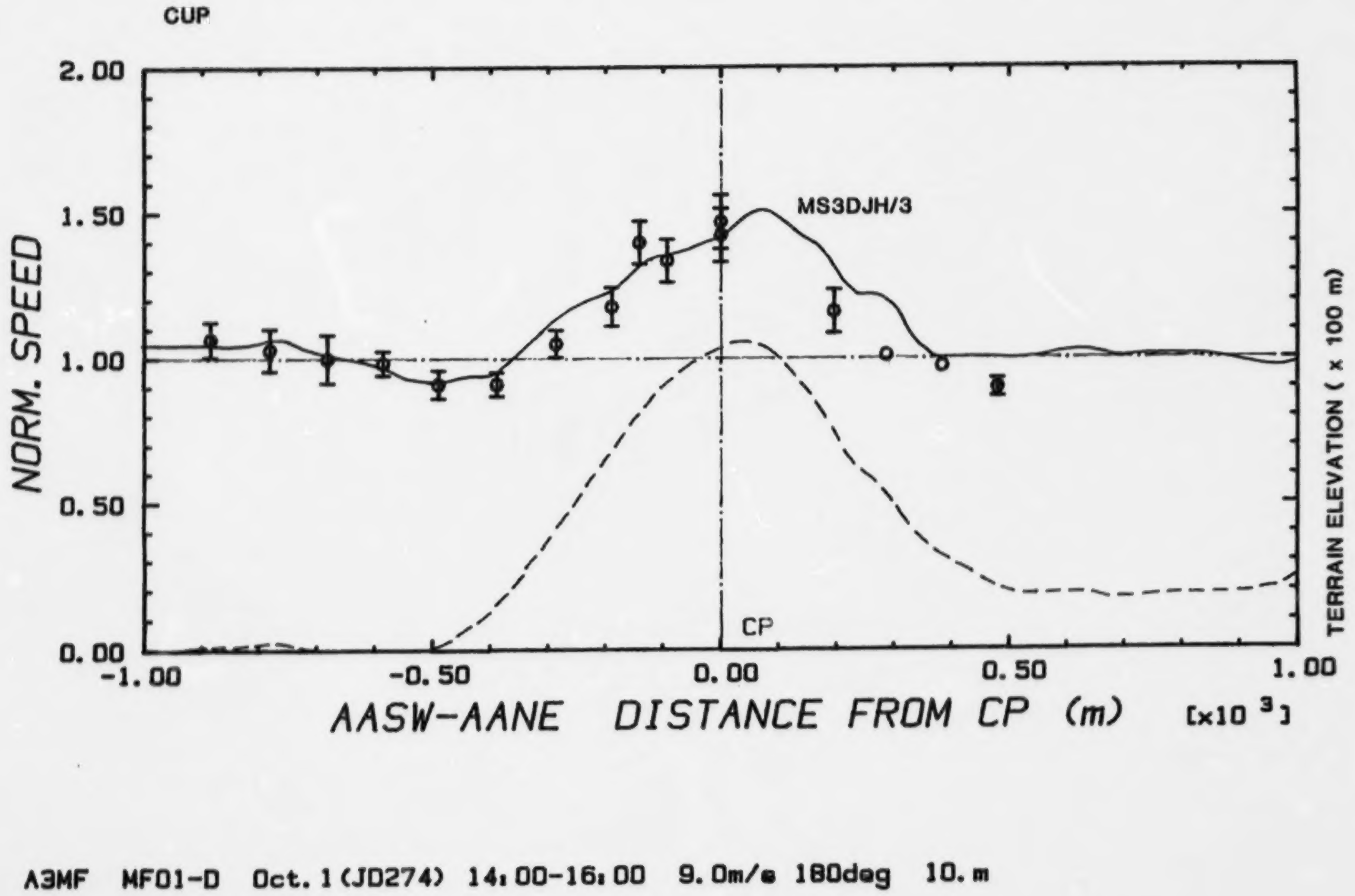


Figure: 5 (c) Upstream wind direction 180°. BNW-BSE cross-section.

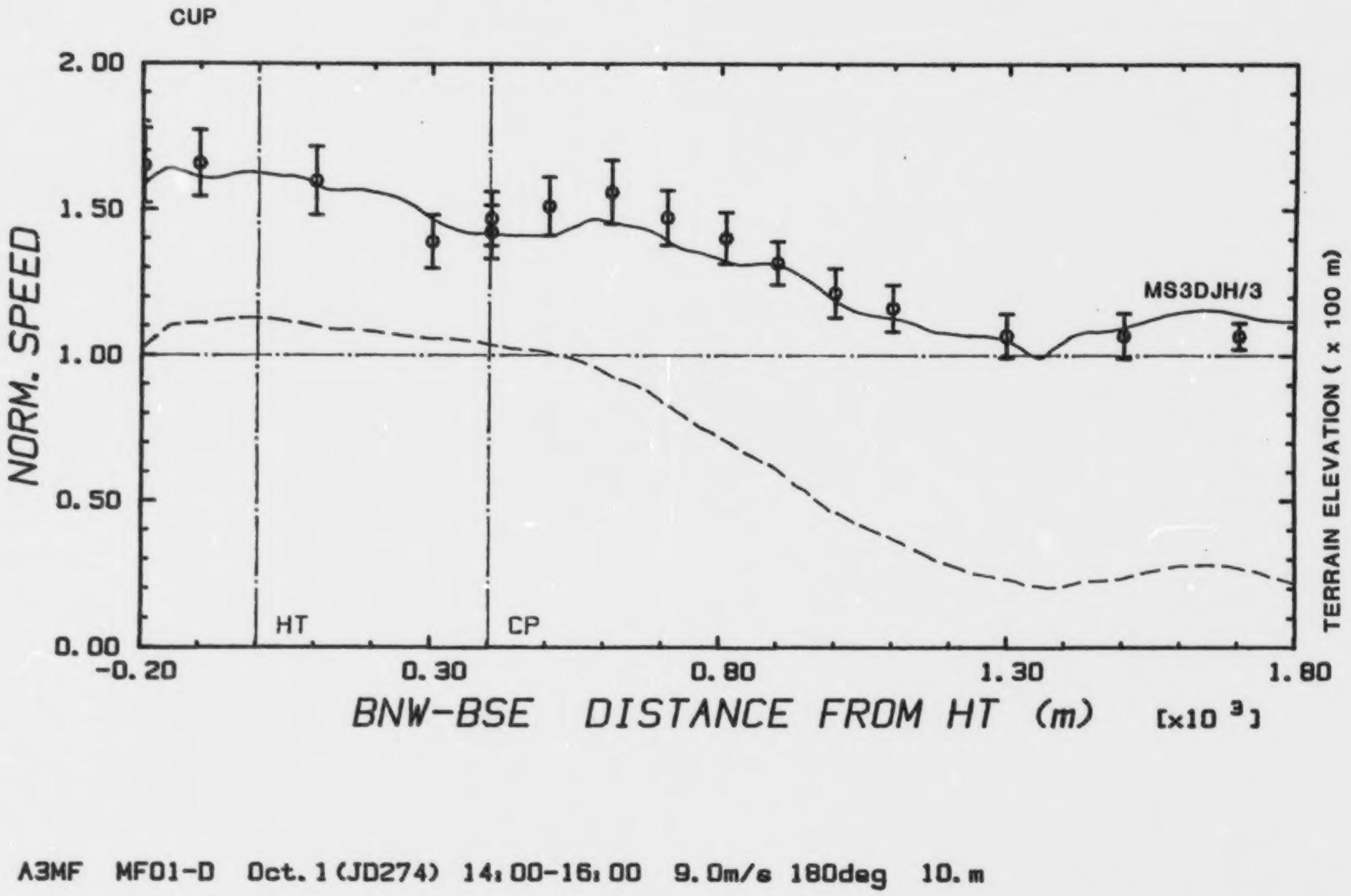


Figure: 5 (d) Upstream wind direction 210°. ASW-ANE cross-section.

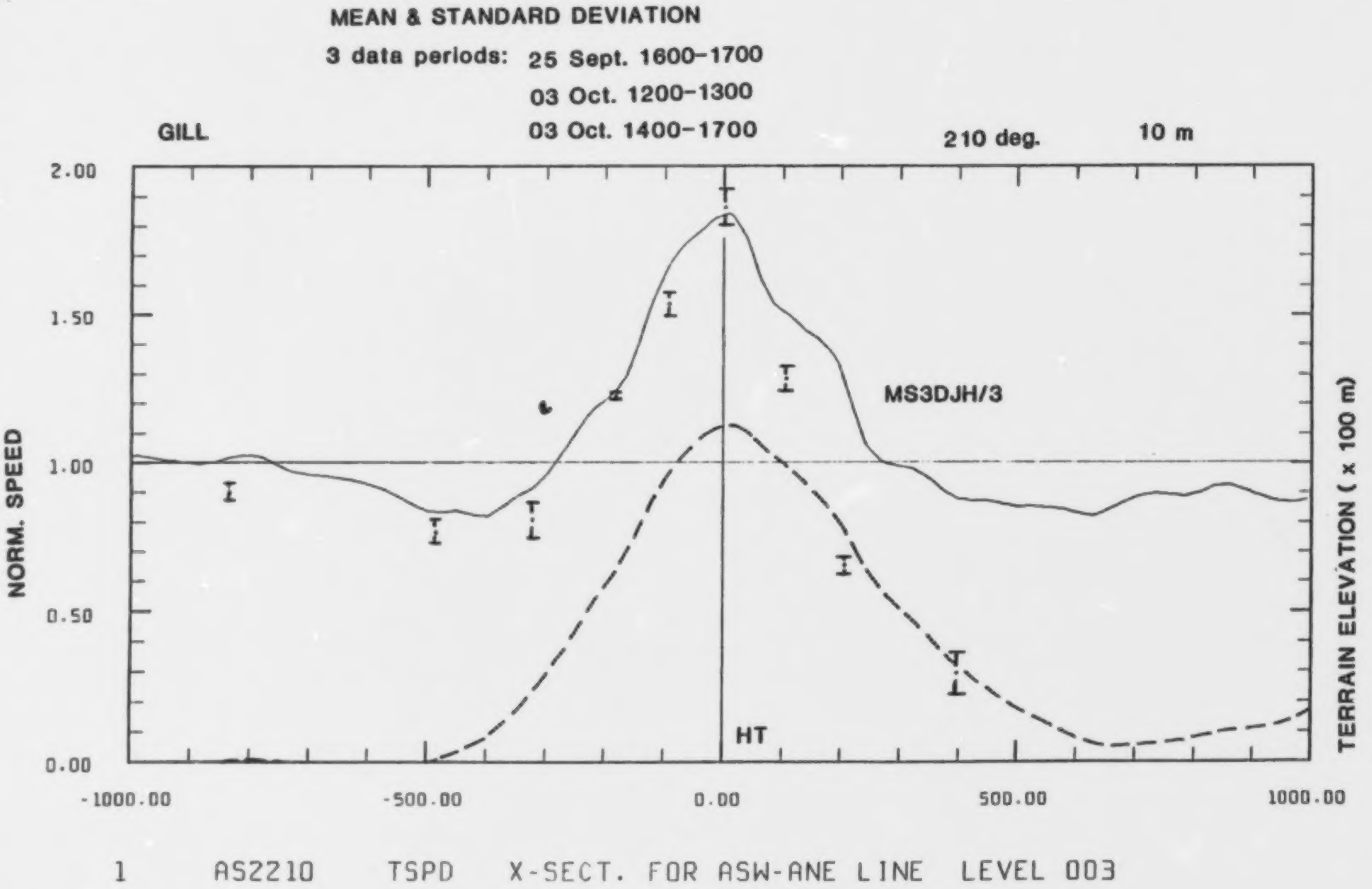


Figure: 5 (e) Upstream wind direction 210°. AASW-AANE cross-section.

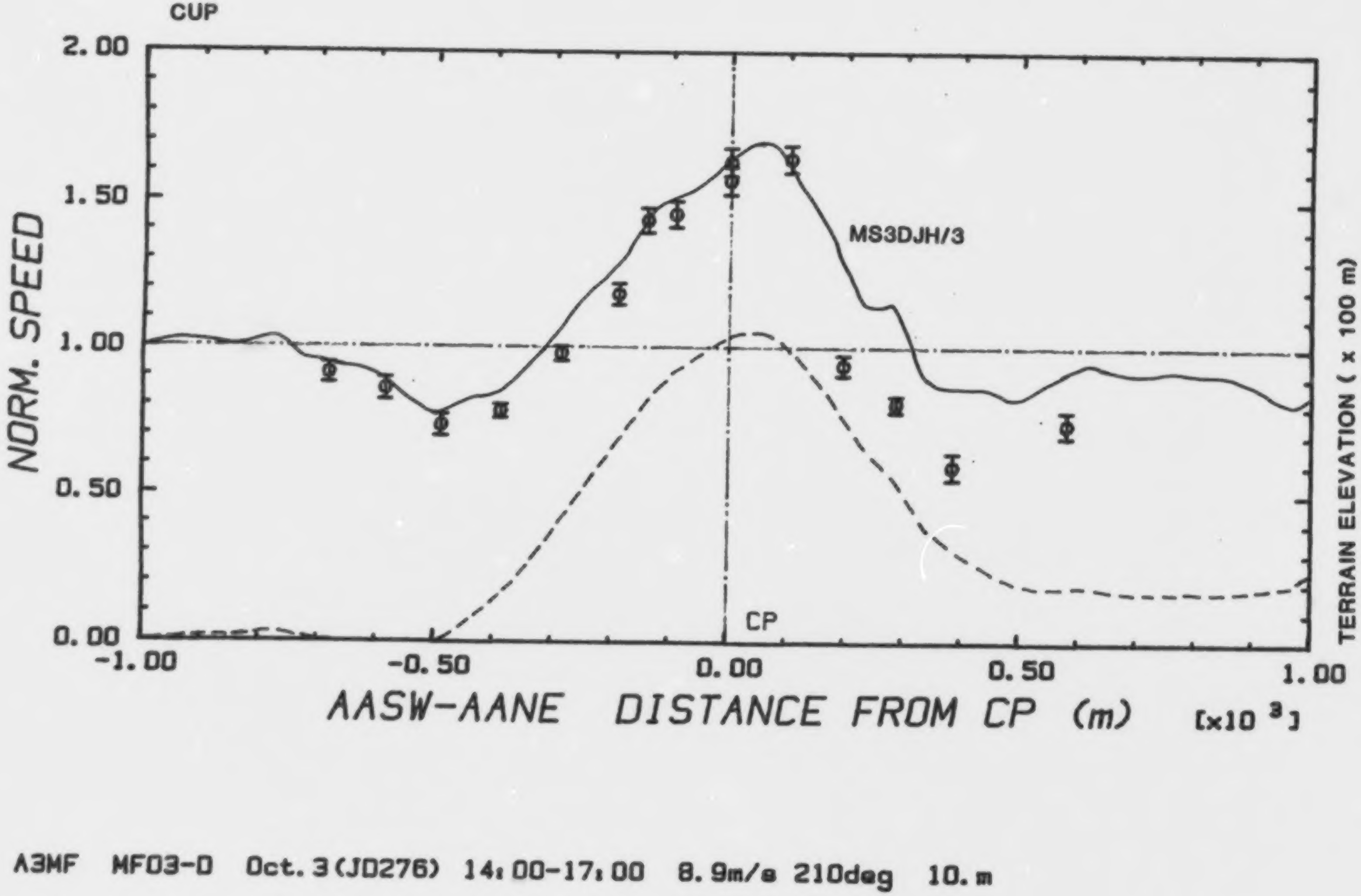


Figure: 5 (f) Upstream wind direction 210°. BNW-BSE cross-section.

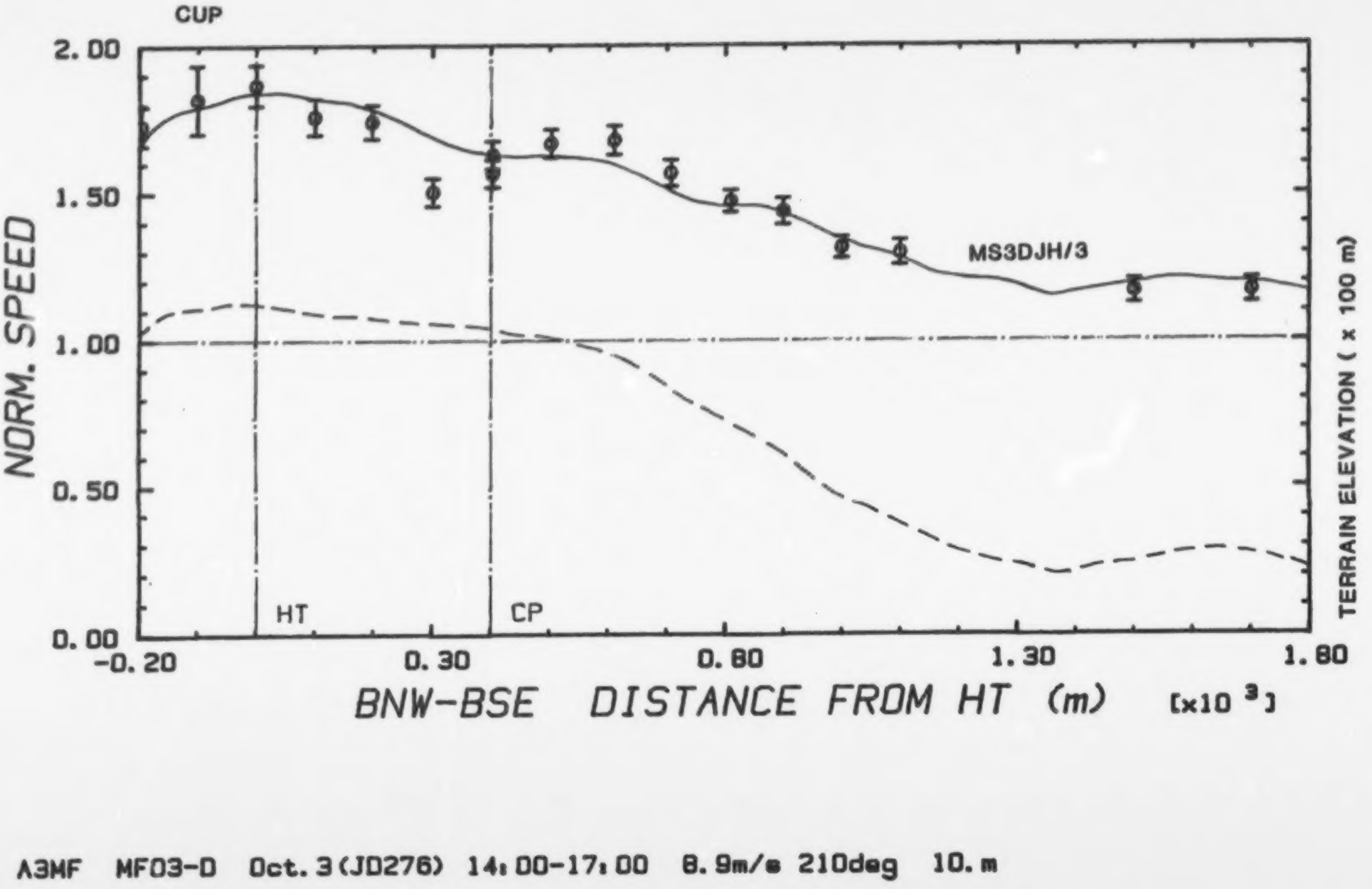
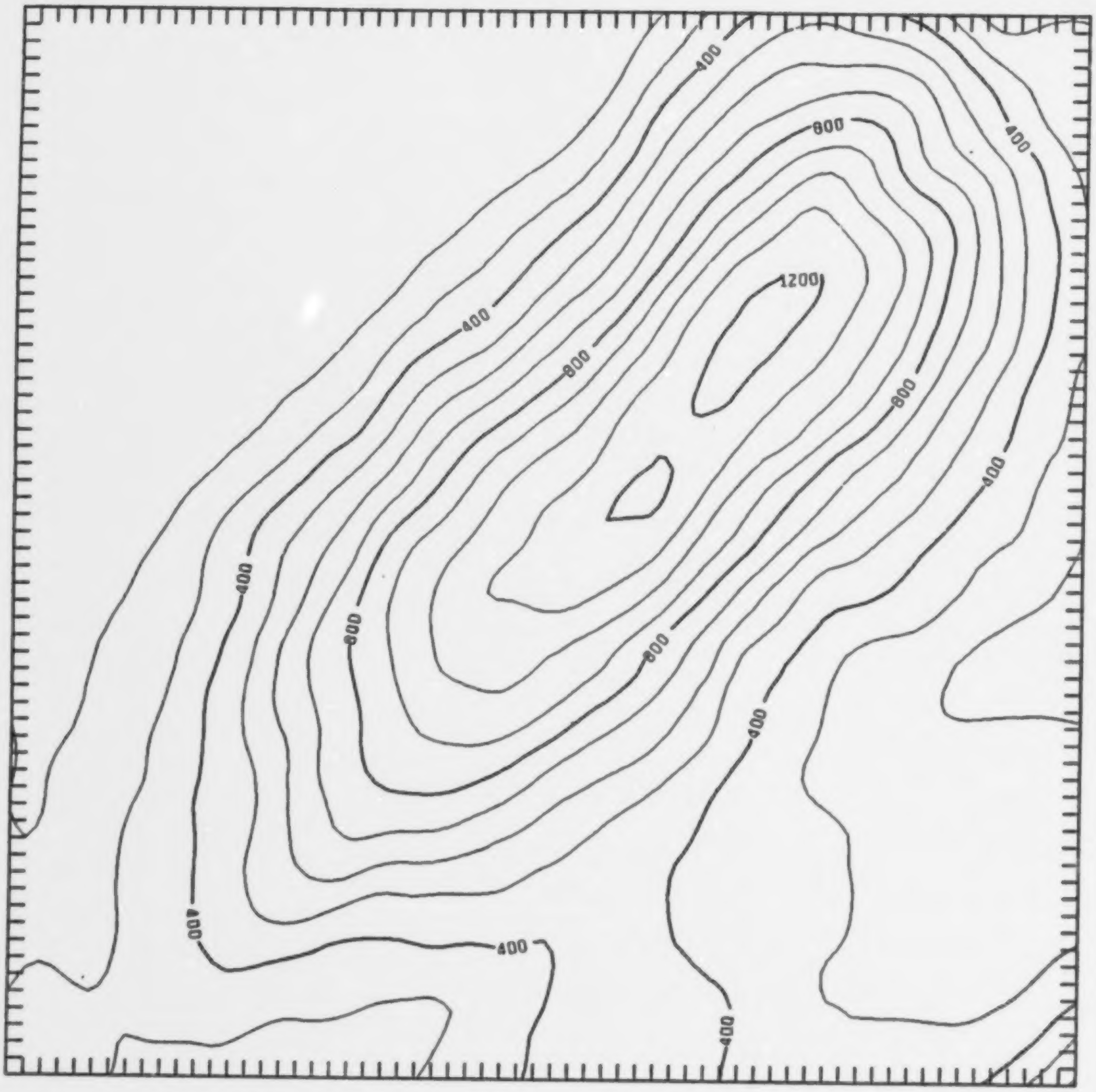


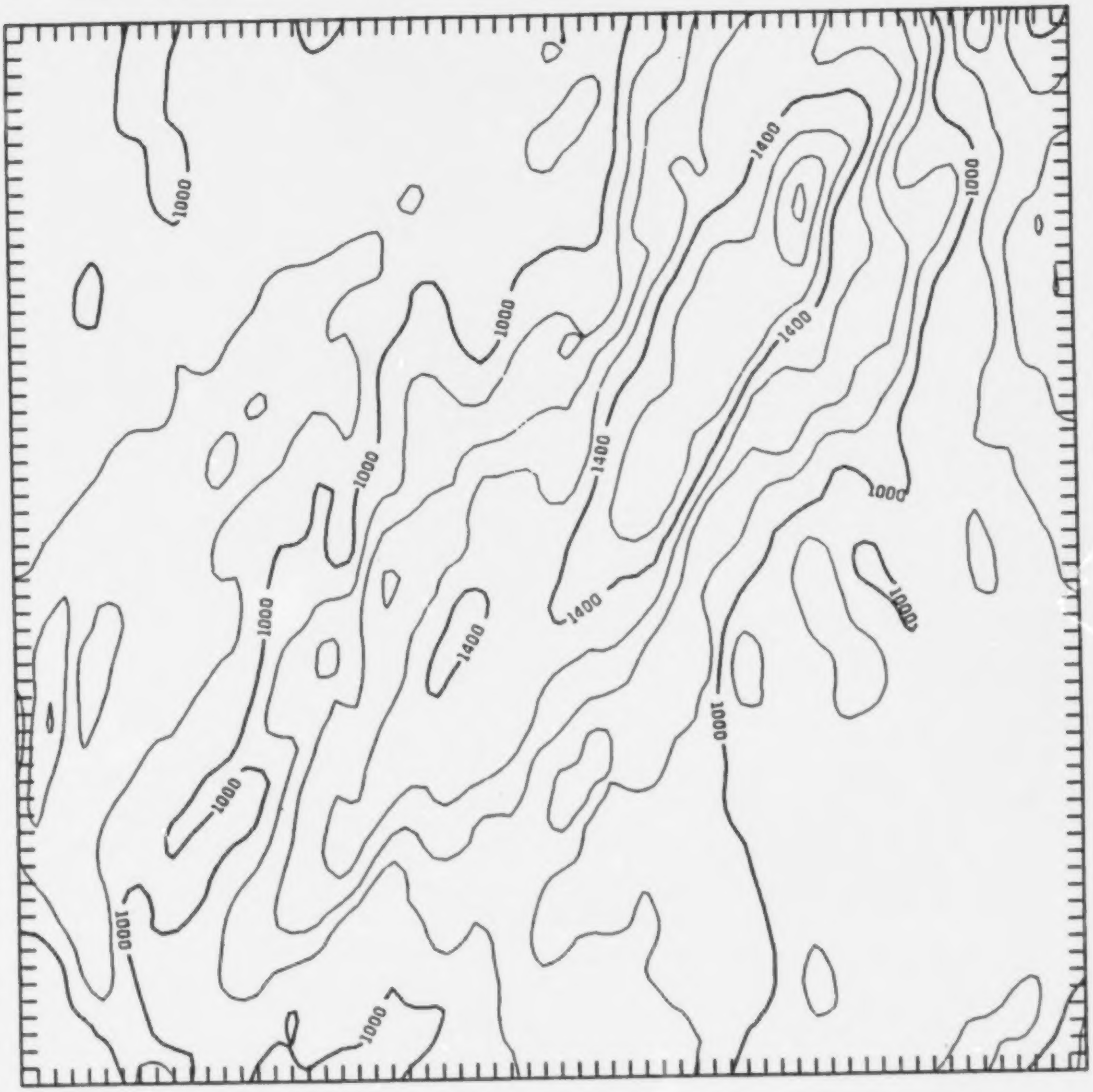
Figure: 6 (a) Terrain elevation.


AS288180 - TOPOGRAPHY (M)
SCALE- 1.E-01
400
800
400
1200
400
800
800
400
400
800
800
400
400
400
400
CONTOUR FROM 0.00000 TO 1200.0 CONTOUR INTERVAL OF 100.00 PT(3,3)= 325.46

Contour maps of Terrain Elevation, Normalized Wind Speed and Wind Direction (relative to upstream direction, positive counterclockwise, dashed lines indicate negative values). Contour intervals are 10 m, 0.1 and 2°, respectively. Values are multiplied by scale factors of 10, 1000 and 100, respectively. Upstream wind direction is 180°, from the left in all diagrams. A central "window" of 64 x 64 gridpoints in the 256 x 256 gridpoint domain is shown. Grid spacing is 25 m in both dimensions.

AS288180 - NORMALIZED WIND SPEED LEVEL- 2 SCALE- 1.E+03

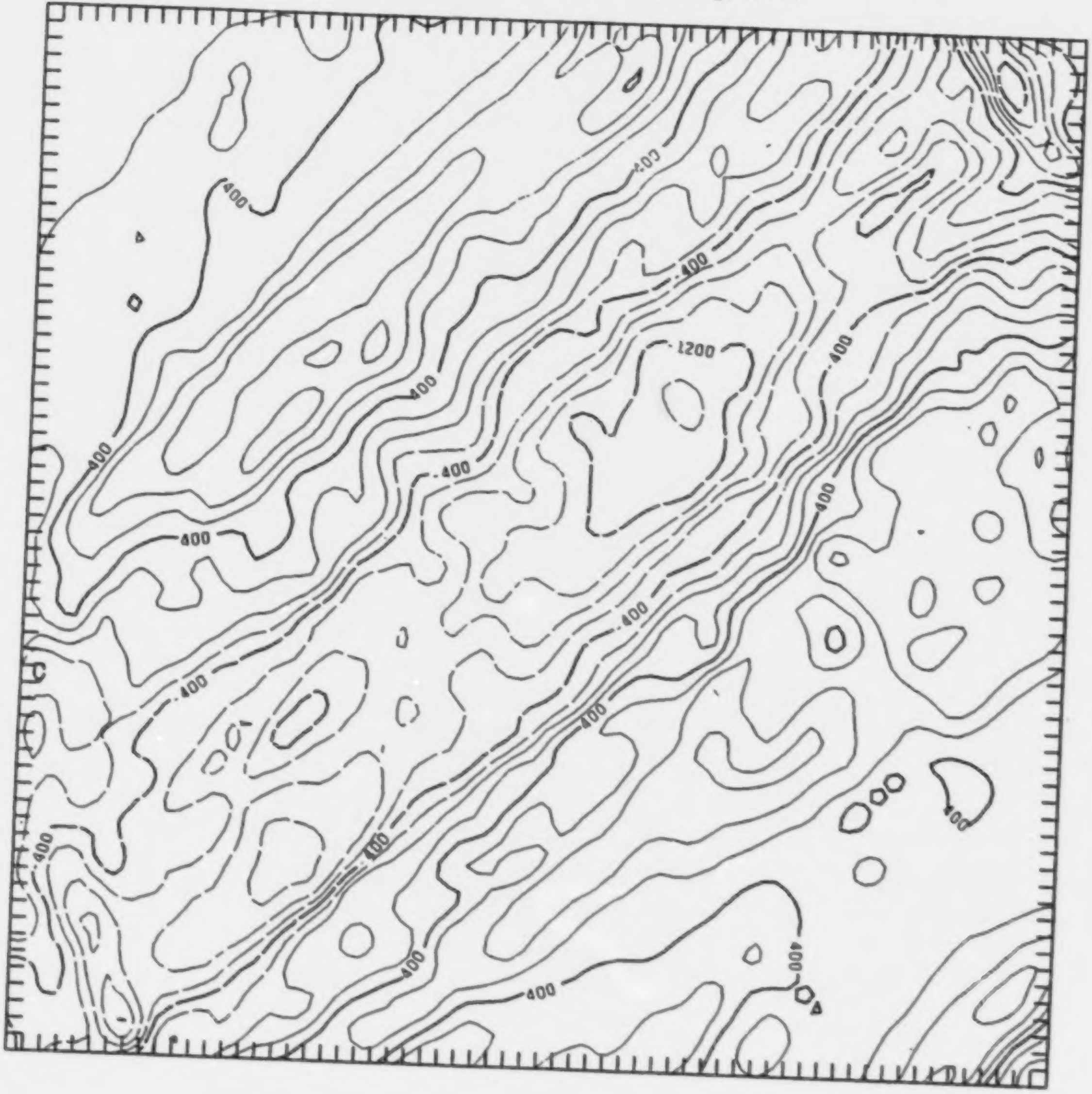
Figure: 6 (b) Normalized wind speed at 10 m above ground.



CONTOUR FROM 600.00 TO 1700.0 CONTOUR INTERVAL OF 100.00 PT(3,3)= 1014.8

AS288180 - WIND DIRECTION (DEG) LEVEL= 2 SCALE= 1.E+02

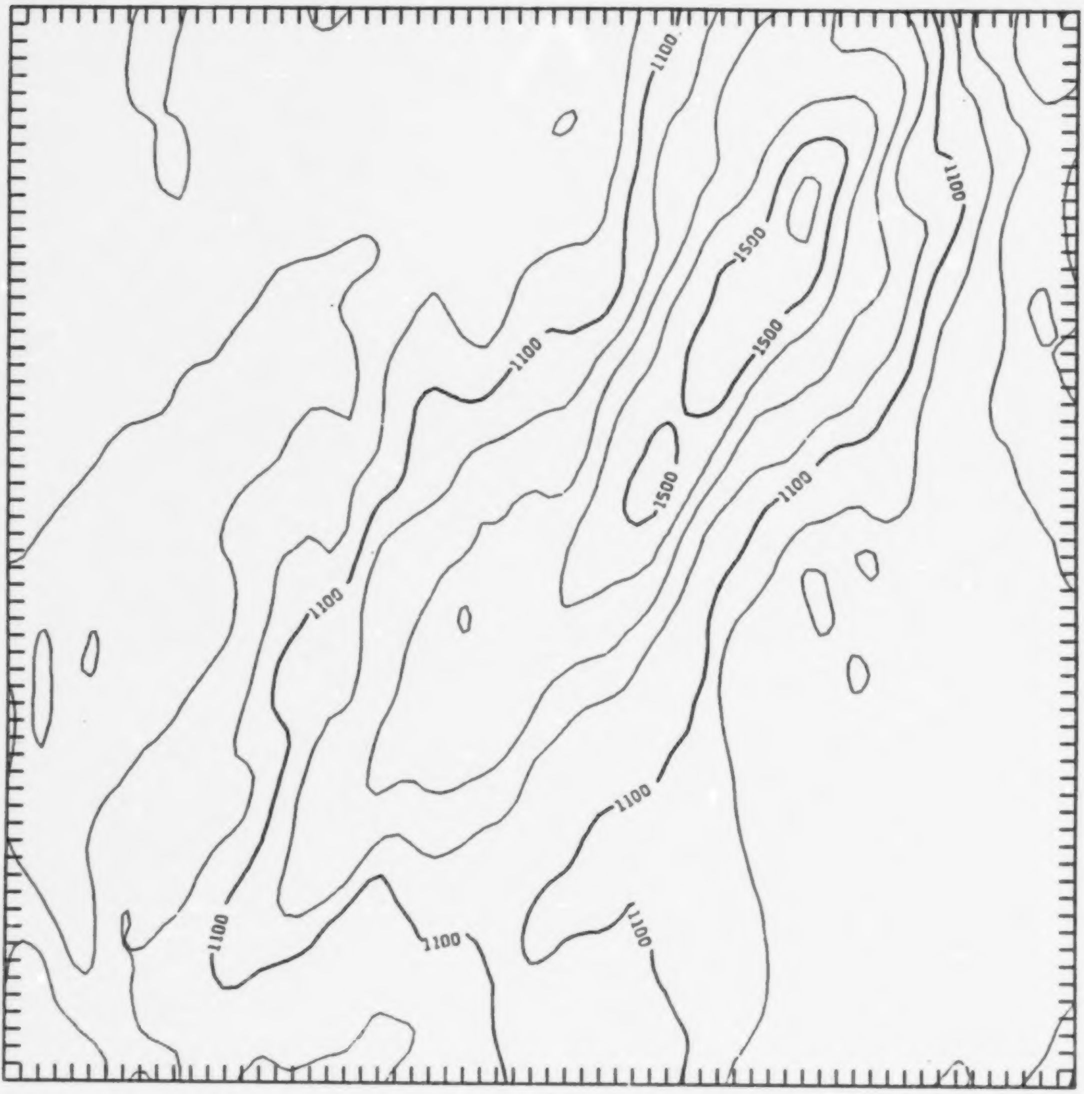
Figure: 6 (c) Wind direction at 10 m above ground.



CONTOUR FROM -2000.0 TO 1200.0 CONTOUR INTERVAL OF 200.00 PT(3,3)= -452.92

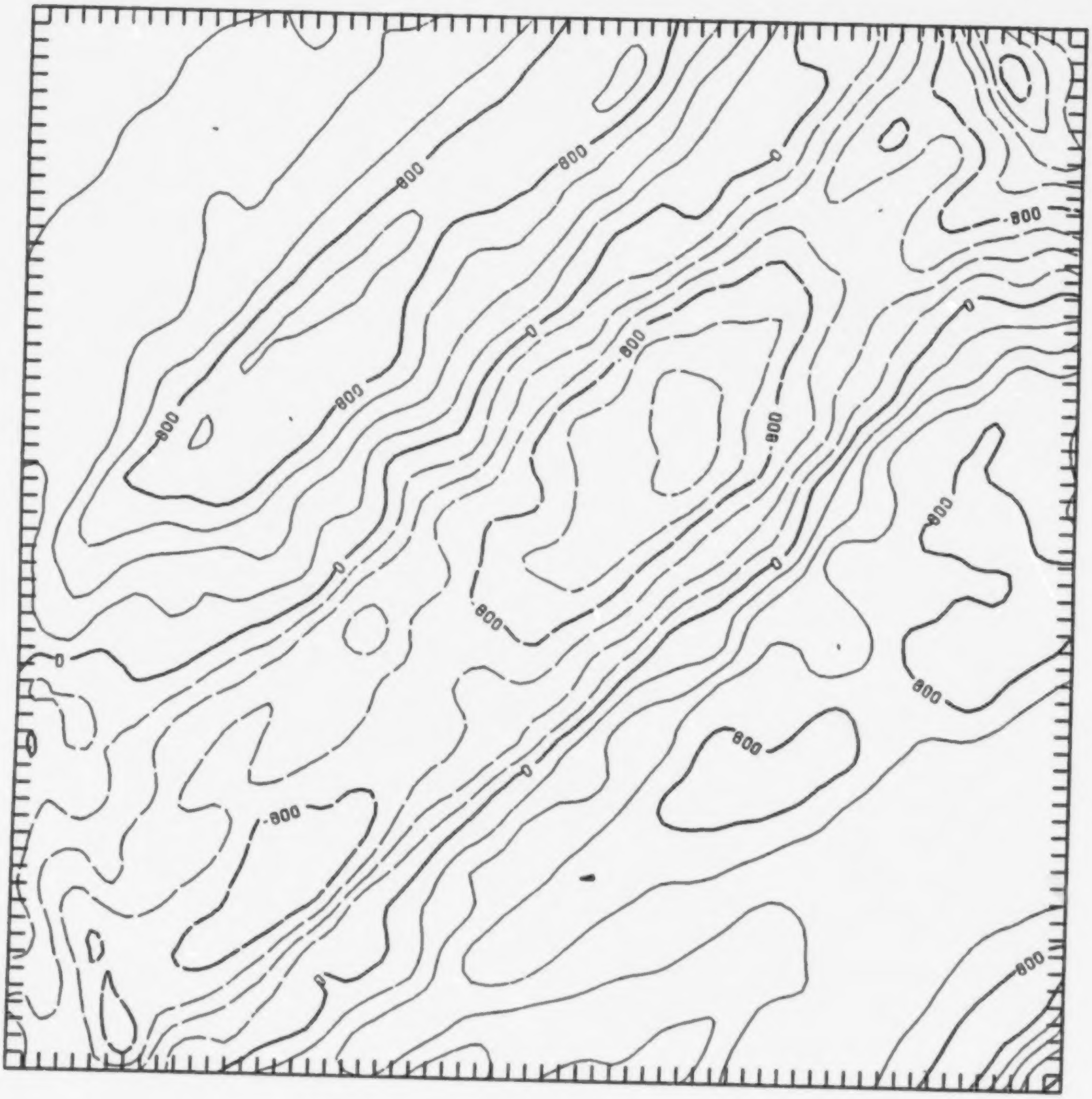
AS288180 - NORMALIZED WIND SPEED LEVEL= 3 SCALE= 1.E+03

Figure: 6 (d) Normalized wind speed at 20 m above ground.



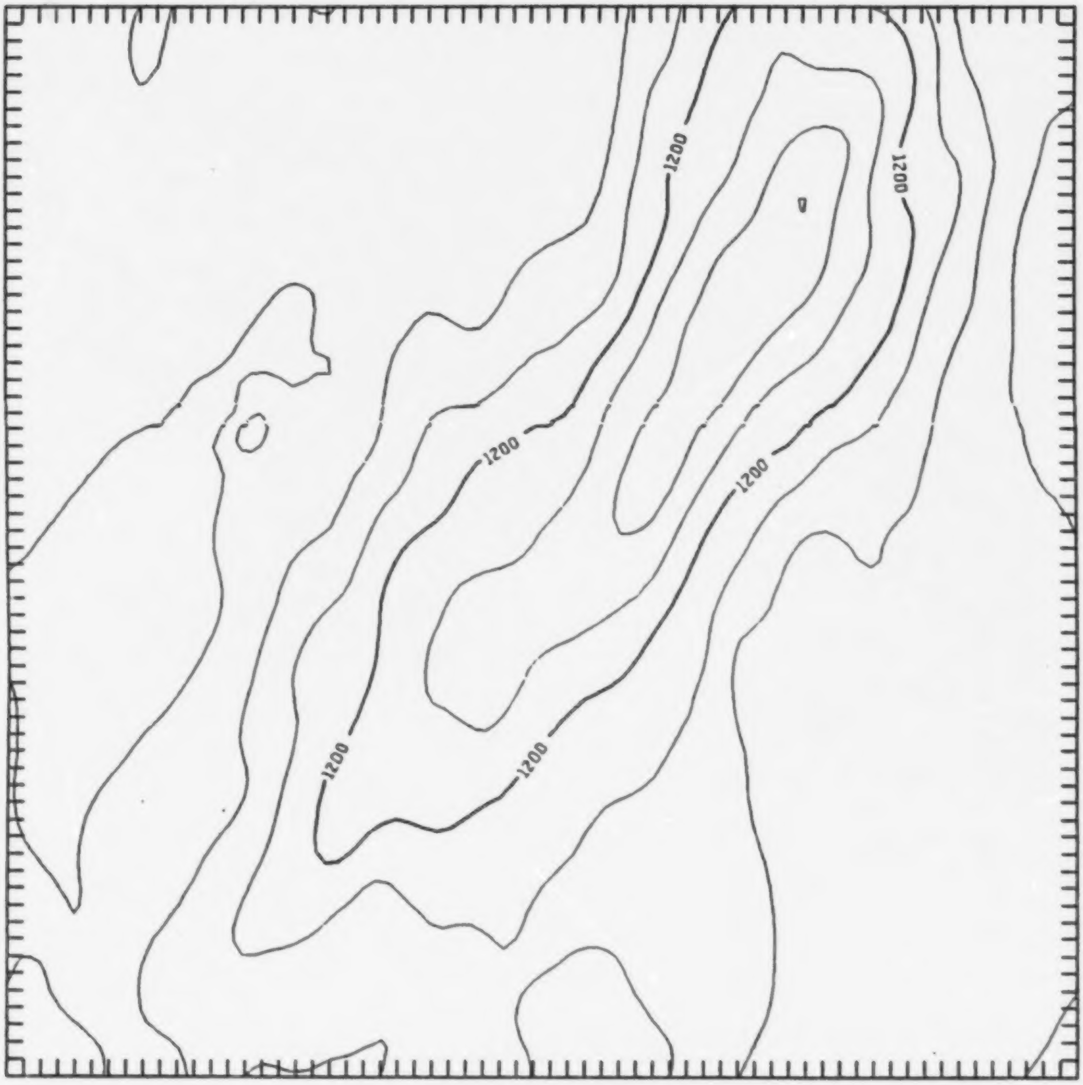
CONTOUR FROM 700.00 TO 1600.0 CONTOUR INTERVAL OF 100.00 PT(3,3)= 1018.2

Figure: 6 (e) Wind direction at 20 m above ground.



AS288180 - NORMALIZED WIND SPEED LEVEL= 4 SCALE= 1.E+03

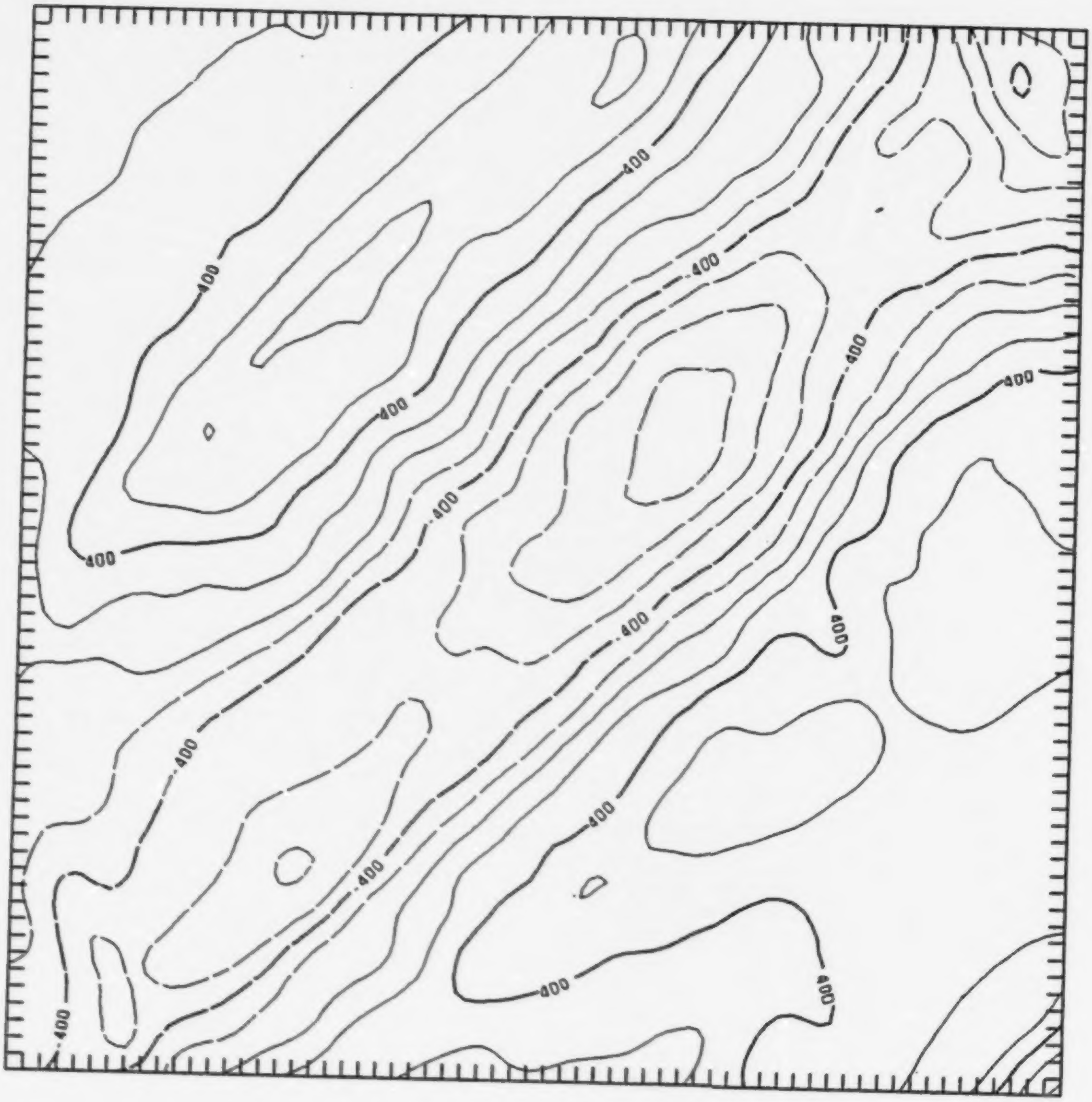
Figure 6 (f)



CONTOUR FROM 800.00 TO 1500.0 CONTOUR INTERVAL OF 100.00 PT(3,3)= 1016.1

AS288180 - WIND DIRECTION (DEG) LEVEL- 4 SCALE- 1.E-02

Figure 6 (g)



CONTOUR FROM -1200.0 TO 800.00 CONTOUR INTERVAL OF 200.00 PT(3,3)= -350.89

'ANALYSIS OF BIN DATA'

R.G. RICHARDS

NATIONAL RESEARCH COUNCIL

CANADA

ANALYSIS OF BIN DATA

Ray Richards, National Research Council

The simplicity of the title of my presentation may be somewhat misleading. The accurate extraction of the steady state performance curve of a WECS from performance data obtained in a turbulent wind is anything but simple.

This could be contrasted, for example, with the performance curved derived from a wind tunnel test in which the tunnel operator can exercise complete control over the environment in which the WECS must operate. In particular, the windspeed remains constant, so it is a relatively simple exercise to establish a steady state performance curve for the WECS at all windspeeds.

Not so for real wind testing of a WECS. The forcing function of real windspeed is simultaneously varying in the amplitude, time, space and frequency domains. This is what complicates an otherwise simple measurement. Any method used to extract the performance curve should consider the data in each of these domains carefully, before placing any confidence in an extracted performance curve.

My presentation today will concentrate primarily on the 'method of bins' technique of performance data analysis, since it is currently the most popular in use.

When using the 'method of bins' to reduce performance data, the system variables of interest are as follows:

- the selected distance between anemometer and rotor,
- the averaging interval chosen for the data,
- the direction of wind velocity, relative to anemometer and rotor,
- the power spectral density of the wind,
- the frequency response or transfer function of the WECS,
- the non-linearity of the true power curve of the WECS,
- the turbulence intensity of windspeed,
- the density of the air,
- the number of measurement entries per bin,

and last, but certainly not least,

- wind shear across the swept area of the rotor.

Time does not permit an exhaustive evaluation of each of these aspects in turn. However, I will attempt to highlight some of the more significant concepts. First an overview of the 'method of bins' technique of data analysis.

Figure 1 shows a typical experimental set up for a performance measurement. On the left we have an anemometer mounted at equator height. It is usually mounted a real multiple of rotor diameters from the WECS, ideally upwind. One is simultaneously measuring windspeed and torque, or electrical power generated by the turbine, at a typical sampling rate of about one second or one Hz.

Figure 2 is a typical plot of windspeed and power taken from a 'real wind' test of a German machine at the Pellworm test site. It was a 22 kilowatt AEROMAN machine, an 11 meter diameter, horizontal axis, wind turbine. This data was taken over a period of two or three days of testing. Power is shown in the upper trace and wind speed in the lower trace. You can see that over a long time base that the windspeed and power are fairly well correlated. But in the high frequency portions of the traces, correlation tends to break down.

If we take the same time series data and plot it as power versus windspeed (See figure 3), we get what my colleague Marc Chappell affectionately refers to as a 'sneeze-plot', for obvious reasons.

This particular plot represents 2000 data points taken at a sample rate of one a second. It is typically elliptical in form. If this particular plot is circular in form we have absolutely no correlation between windspeed and power measurements. The more laterally elliptical it is, the better the correlation.

The 'method of bins' takes this performance data and divides the windspeed axis into a number of class intervals. In each class interval, the average of the windspeed is measured and plotted. In the lower trace, we have a plot of the average windspeed in each bin. This particular run, which was about an hour's duration, was actually taken at the Atlantic Wind Test Site in Prince Edward Island for a 17 by 11 meter VAWT. This particular power curve is almost horizontal as you would expect from a plot which has this sort of elliptical shape.

This data can be tabulated and a header page produced (See figure 4) showing all the usual test conditions that were present when the test was performed. We, of course, have:

- a record of the start and stop time of the test. In this case, it is about an hour's duration.

- we also monitor the:

    - temperature, degrees Kelvin,
    - the average pressure,
    - the air density,
    - the average windspeed for the run,

- we also calculate the:

    - standard deviation of windspeed recursively,
    - the direction of the wind,
    - the turbulence intensity, of course, which can be obtained by dividing the standard deviation of the wind with the average windspeed. In this case, it was about 17 per cent or so.
    - the average power
    - the standard deviation of power again recursively,
    - the energy available in the wind
    - and - the actual energy produced by the turbine.

This particular reading of efficiency, which is 57 per cent, is a little optimistic, to say the least. As it turned out, for this particular run there was an error in the measurement of windspeed. This figure is very sensitive, of course, to average windspeed. This technique is a good check on these parameters when they are measured.

Again the number of observations and the sampling interval, being one second in this case. The windspeed bins over which these power data are entered, vary from 3.5 meters per second to 11.5 meters per second. You can see the number of entries in windspeed and power in each of these bins, with a peak occurring somewhere around the 7.5 meter per second bin. Please note that this is slightly above the average windspeed of 7 meters per second. This is typical for a Weibull distribution coefficient of about 2. Mean power is entered here and the standard deviation of power in this column.

Figure 5 attempts to explain why we generally speaking have a lack of correlation between windspeed and power measurements that are taken simultaneously using relatively short sampling intervals.

Let us look at the wind and assume, for example, that Taylor's frozen wave hypothesis of turbulence is valid within the vicinity of the anemometer-rotor set. What this hypothesis essentially says is that the turbulence structure is frozen and moves along at the average windspeed.

Let us consider the turbulence as being composed of an infinite Fourier Series. Each term has an amplitude which varies in the series. Each component has it's own wavelength associated with that particular frequency. For long wavelength or low frequency components of the series, windspeed and power should be relatively well correlated. But for high frequency variations, I'm particularly looking at this one here, we can see that windspeed is actually dropping, while power is actually increasing. This results in scatter of the data. This effect was observed and, I believe, first recorded by Mr. Christensen in experiments at Riso. It was dubbed, "the stepping effect", I believe, in Canada.

I can show this if I go back to figure 3, where you repeat these performance tests at average windspeeds higher or lower than that shown here. You see that you get a series of horizontal lines. If you connect these horizontal lines you get steps in the curve. This is why it is called 'the stepping effect'.

One fairly simple method of getting around the problem of 'stepping effects' is to average the data. This numerically filters out the turbulent components of windspeed to leave only the long wavelengths or well correlated turbulent components in your data set. When you numerically average, or arithmetically average, you are actually multiplying the 'power spectral density of windspeed and power' by the function sin X over X. This is essentially a low pass filter function that eliminates the high frequency components of windspeed and power which results in improved correlation.

Moving the anemometer closer to the WECS, also improves correlation, as you can see by considering this top curve.

Taking the one second data and averaging it over a ten second interval, gives you 10 second data points as plotted in figure 6. After binning that same information down here, you can see that this line is now rotated counter clockwise, from the horizontal. It is pretty much rotated into the position it should be in. We carry this further by taking the 10 second data and averaging it over a minute (see figure 7). You can see the standard deviation of the data also has dropped with, presumably, a further improvement in correlation. Again, averaging over 10 minutes in this case, we are left with only three data points for this particular run.

Figure 9 shows the standard deviaton of windspeed and power as a function of averaging time. The averaging interval was varied from zero seconds to 600 seconds, which represents 10 minutes. If you drew a line through these data points, you can see that the standard deviation of windspeed and power decreases rapidly to about a one minute averaging time, where we meet the knee of the curve, and then levels out. The same thing happens approximately with the power measurements.

Perhaps you are familiar with the AWEA standard and the IEA standard of performance measurements. The averaging time for the AWEA standard is recommended as one minute and for the IEA standard it is 10 minutes. You can see from these curves that the difference in standard deviation isn't that great between the two averaging intervals.

Figure 10 again represents the scatter plot of the German turbine I mentioned earlier. In this case, the anemometer is located only 1.5 rotor diameters directly upwind of the rotor, so correlation is quite good in this plot.

This could be compared with figure 11, in which the anemometer is located 27 rotor diameters directly upwind of the rotor. You can see there's considerable increase in the standard deviation of the data although the average trends are still quite clear.

Some computer simulations of this problem were performed at the Atlantic Wind Test Site. We were interested in determining the effects of anemometer-to-rotor spacing on the population correlation coefficient of the data. In figure 12, we plotted the population correlation coefficient as a function of the number of rotor diameters of separation between the anemometer and the rotor, and also the averaging interval. The averaging interval was varied from one second to 60 seconds. You can see that there is a very rapid decrease here. At roughly 3 rotor diameters, we have approximately zero correlation for a one second averaging interval. When we increase the averaging interval to 60 seconds, the correlation is again improved considerably. This computer simulation also assumed, that Taylor's frozen wave hypothesis was valid in the vicinity of the rotor-anemometer set and that it was valid out to 25 rotor diameters. This may be extending this assumption considerably because we haven't accounted for shear or viscuous dissipation of turbulent energy in the flow. But I think the general trends that are there are shown.

There is another interesting aspect of the testing of wind turbines using 'the method of bins', or any other method that uses arithmetic averaging of the data. In each bin there is an effect that I don't believe has been accounted for in the literature up to this point. This is the non-linearity of the true performance curve of the wind turbine.

In figure 13, we assumed a theoretical or true power performance curve. We then applied a sinusoid of windspeed, moving around the average, and projected this onto a performance curve around the peak of the curve. We can see that the resulting power output is distorted. This effect depresses the average that one would measure using the 'method of bins' or any other averaging technique. Therefore, the actual performance measurement or data point occurs here in the measured data, rather than here, on the true curve.

The opposite effect occurs in regions of power curve 'positive concavity'. Here we actually have an increase in average power, so we tend to overpredict the power curve in this region.

These results were brought to light in the simulation model. They have not been confirmed in real wind testing. We have a lot of effects occurring up here in the dynamic stall region, as Jack Templin and Lawrence Schienbein, amongst others, pointed out this morning. This is simply another effect which the data analyst has to take into account when reducing this kind of information. Again, I remind you that this is still fairly theoretical. Although we haven't made measurements in the real wind to confirm this effect, it appears that it is something that is worth considering.

Figure 14 shows that the general result of these effects is to produce a depressed, measured power curve in regions of severe non-linearity of the true curve. We tend to have rounded shoulders rather than nice sharp shoulders in the power curve.

The bias in the power curve due to turbulence of can be computed if we make a few assumptions (See figure 15). First of all, if we assume that we can fit the measured power curve to a polynomial of the third order exactly, we can compute the percent deviation from the true power curve for any level of turbulence intensity. On the X axis we have this parameter, $K(T.I.)^2$ which represents the turbulence intensity of windspeed. This factor K represents the percentage of energy that the wind turbine can extract from the turbulence. In other words, it accounts for the frequency response or the response of the WECS in the frequency domain.

This parameter B accounts for the non-linearity of the performance curve itself. These 'b' coefficients and 'a' coefficients are the coefficients of the polynomial used to fit the experimental curve. The B = 3 line represents a wind turbine which has a pure cubic power curve. The B = 0 line represents a turbine which is totally linear and for which turbulence has no effect on the extracted power curve. In reality, we expect to see the parameter B in this range (i.e. between B = 0 and B = 3). It can also go negative depending on the curvature of the power curve.

Extending this a little further in figure 16, we can develop corrections for the non-linearity effects and turbulence intensity effects. We have a true power curve represented by a third order polynomial and the measured power curve represented by a third order polynomial. We find that the true coefficients can be expressed in terms of the measured coefficients if we perform the indicated transformation, that is division by this term and this term. Here again K represents the percentage of energy that the turbine was able to extract from the turbulence.

There are additional problems to 'stepping effects', averaging interval and the non-linearity of the power curve (See figure 17). We have to determine in a performance measurement the minimum number of observations of windspeed and power necessary for statistical validity in each bin.

Presently, the IEA standard recommends 10 ten minute averages per bin for a total data set of 3000 ten minute averages for all bins.

The AWEA standard recommends 40 one minute averages per bin, below 12 meters per second. Then, 20 one minute averages per bin for the 12-15 meters per second windspeed range. Finally, 10 one minute averages above 15 meters per second. Clearly the standards are divergent. They haven't met on a common ground at this point.

The true average of power in a windspeed bin can only be obtained if we take an infinite number of readings of windspeed and power (See figure 18). Therefore, we must be content with an estimate of that average, given by this simple relationship. The way around this problem is to make a confidence statement about the estimate $\overline{X}$. This parameter is the measured mean or experimental mean relative to the true mean, u_x.

Define an interval about the estimate within which we are P per cent certain that the actual mean of the bin is contained. This relationship defines that interval. The true mean of the bin is contained within this outside interval. This interval is proportional to the standard deviation of the X_i samples within that bin and inversely proportional to the root of the number of observations within that bin. It is a function of the Student's 't' distribution. This distribution is a function of the number of observations and the factor alpha which is defined as 1 minus P over 100. Of course, N must be greater than 1.

This can be interpreted in the following way. Figure 20 shows a segment of the power curve. This is the experimental mean within any particular bin. This is the standard deviation of the N readings within that bin. Somewhere on this line, lies the true mean in that bin, the u_x. The relationship shown in the previous slide defines the confidence interval on the true mean within that bin. It may be desired that P per cent confidence in the performance curve, on a bin by bin basis, be kept within plus or minus D per cent of the sample mean. In that case, we have to use the expression shown (See figure 21). This is D per cent. Note again the root of the number of observations and the Student's 't' statistic.

The CSA standards being developed on performance measurements proposes use of this technique. We set the confidence interval on the measurement of the true mean windspeed in each bin, rather than arbitrarily selecting a particular number of entries per bin. Perhaps this might be made a little clearer by illustrating the concepts with an example.

In figure 22 we have ten observations. We wish to be 99 per cent confident that the true mean is within plus or minus 2.5 per cent of the sample mean. In this case the sample mean was 14,710 watts for the 7.5 meter per second bin. This was taken from the previous example shown. We have a standard deviation of 858 watts in that bin for ten 10 minute averages. This yields an alpha of .01. Dividing alpha by 2 in order to use the tables of the 't' statistic, we find for alpha = .005, that t = 3.25. To meet the confidence requirements that we desire, we have to have a standard deviation for these values of less than or equal to 358 watts. A standard deviation of 858 watts does not meet this requirement. The only way we can meet this requirement is to increase the number of samples and reduce the standard deviation in each bin.

If that is increased to 40 - ten minute averages, the Student 't' statistic drops to 2.7 (See figure 23). The required standard deviation becomes 861 watts which meets the needs of the measurement requirements. Consequently, the measurements would proceed until the standard deviation requirements in each bin were met. This process would establish the minimum data base requirements for each bin.

In summary, then, it is apparent that the 'method of bins', without turbulence effects correction, closely predicts the true performance curve in regions of power curve linearity. In regions of power curve non-linearity, i.e. regions of negative or positive concavity, the estimated performance curve was shown to deviate from the true performance curve as evidenced by the simulation results. This deviation was shown to be not only a function of the square of the turbulence intensity, but also a function of the non-linearity of the performance curve and the frequency response of the WECS.

As illustrated, the use of 10 minute averages does not eliminate the effects of WECS performance curve non-linearity on the extracted performance curve, if the time constant of the WECS is much shorter than ten minutes.

The actual energy produced by the WECS is independent of what averaging interval the data analyst uses when reducing power and windspeed performance data. Therefore, post filtering of the data through time averaging does not eliminate the effects of turbulence on the actual production of energy, nor does it allow for an easy extraction of the true constant wind performance curve. Time averaging of the performance data does improve correlation between windspeed and power and therefore reduces the problems associated with 'stepping effects'.

It was shown that averaging intervals of one minute or greater will usually provide considerable improvement in windspeed versus power correlation when rotor to anemometer spacing is kept at approximately 2-10 rotor diameters and when the anemometer is directly upwind of the WECS.

As the number of observations over which an average is taken is increased, the standard deviation of the average decreases by the factor 1 over the root of N. This is particularly noticeable when comparing one second and ten minute averages of the same raw performance data. This decrease in standard deviation, as averaging time is increased, in no way reflects an improvement in accuracy of extracted performance curves. The data analyst should keep this in mind when calculating long term averages such as those obtained when using one or ten minute averaging intervals.

The question of minimum data base requirements was addressed. It appears that 'establishing the limits of confidence on a bin by bin basis for an extracted performance curve' is a useful tool in determining the number of data entries required to meet any desired level of confidence in the estimate of the true bin average. This is preferable to somewhat arbitrarily selecting a fixed number of data entries per bin without first considering specific statistical goals for performance measurement.

This concludes my presentation. Thank you.

Q. I am not sure I understand your 'stepping effect', maybe I'm missing something there.

A. Okay, the 'stepping effect', really is lack of correlation between windspeed and power measurements, so the power...sorry...

Q. Are those time-delayed correlations you were doing?

A. No, we were looking at instantaneous samples of windspeed and power.

Q. So, if the anemometer were truly upstream of the windmill and if Taylor's hypothesis was valid, surely you would get 100 per cent correlation?

A. No, no. Only for long wavelength components of the turbulence. They are fully correlated...

Q. Because if it's truly 'frozen field' all you are doing is taking the input and moving it, translating it by the mean speed to where the anemometer is. Then any loss of high frequency information surely is the response of the windmill.

A. At any instant in time the correlation between windspeed and power must be poor, because you may have a gust front at the anemometer and a lack of one at the rotor on an instantaneous basis. So you may have power dropping with windspeed simultaneously increasing at a given time.

Q. Okay, that's why I'm confused. Surely that goes away when you translate the frozen pattern, the frozen waves you showed, the high frequency waves....?

A. Well, if you account for the delay between anemometer and rotor, then yes, you get good correlation. But generally speaking, this isn't done. It can be done and it does help to improve correlation.

MALCOLM LODGE

I think you fellows better sit together at dinner.

Q. The averaging does that. Helps that way.

MALCOLM LODGE

Thank you very much, Ray. We must move along.

Figure: 1 **AEROMAN 22 kW SWECS installed at Pellworm Test Site, Germany**

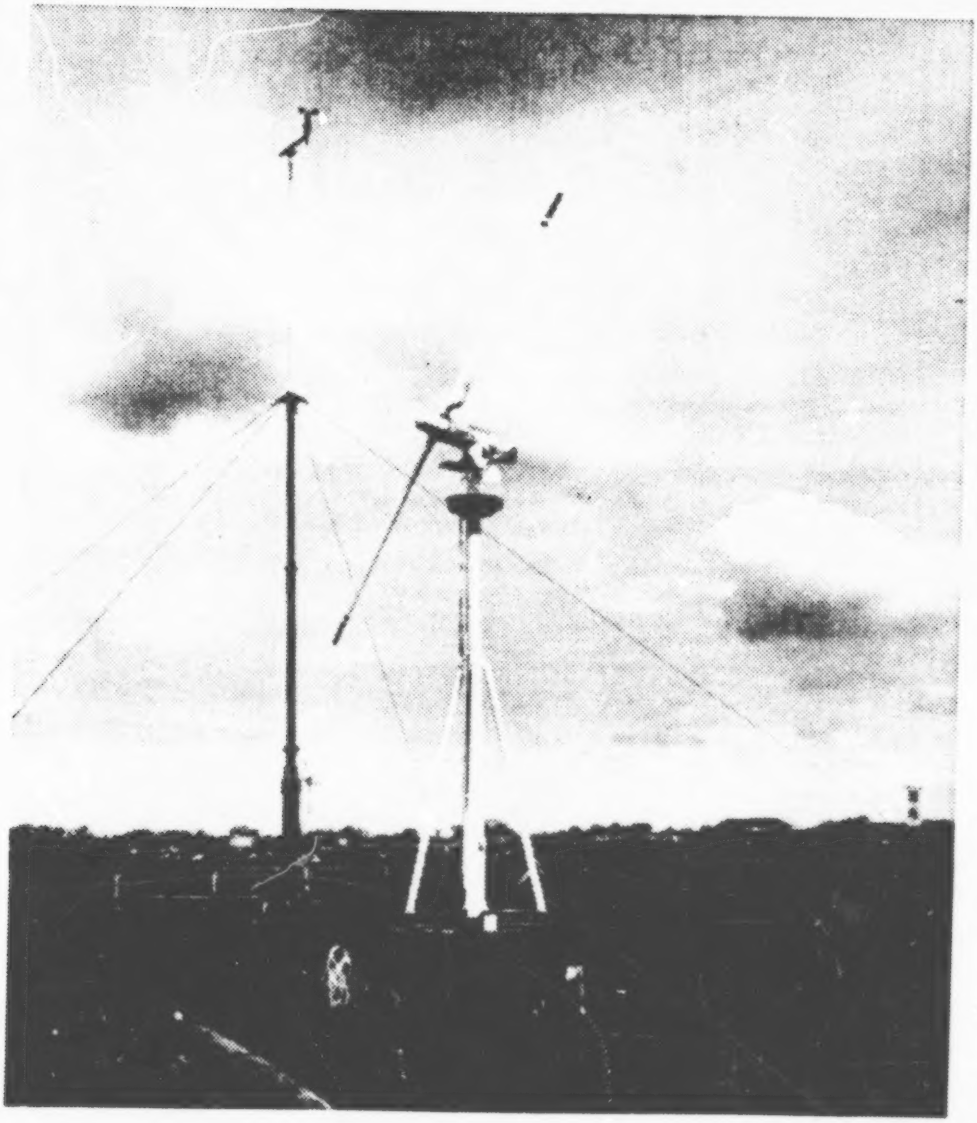
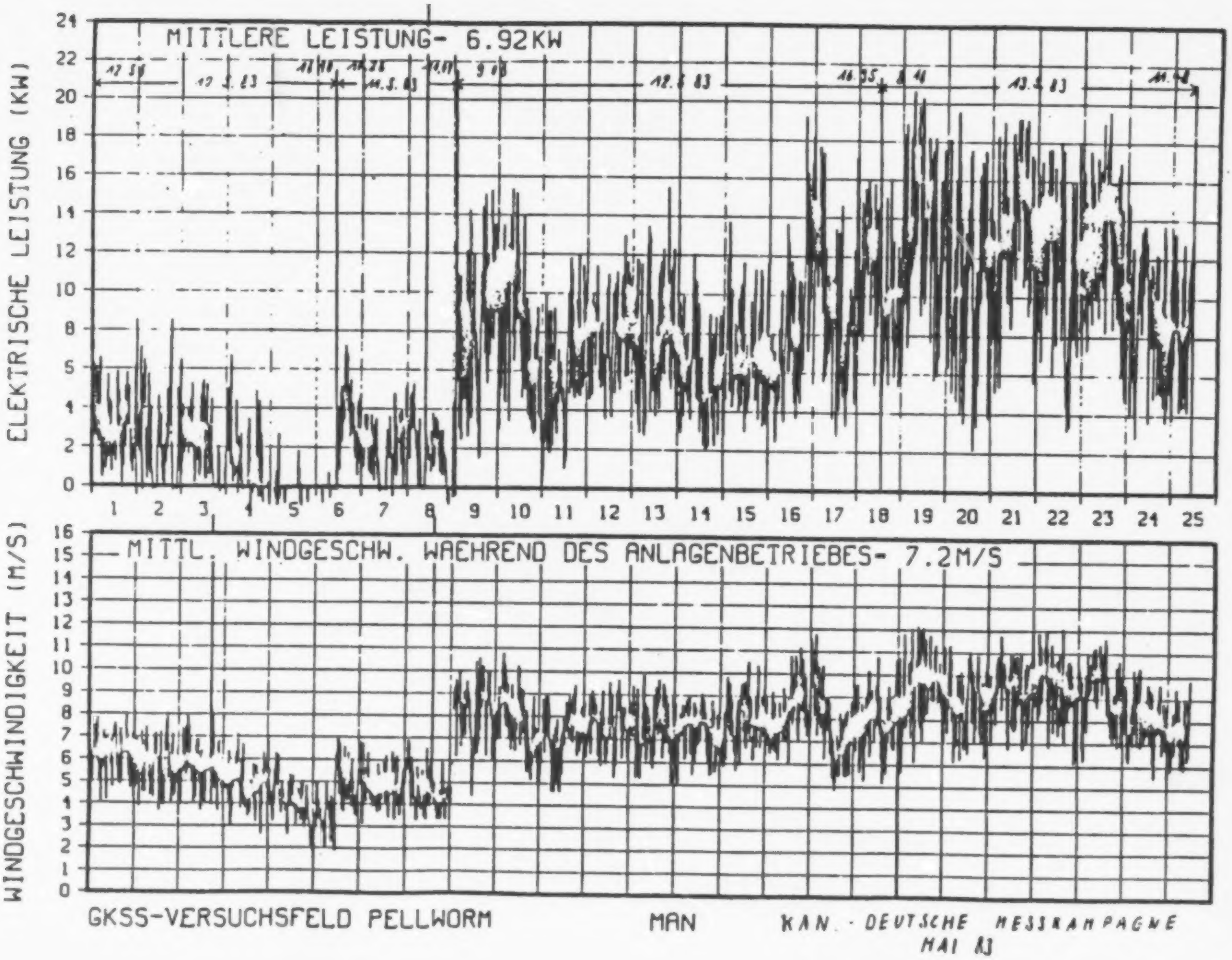


Figure: 2


MITTLERE LEISTUNG- 6.92KW
ELEKTRISCHE LEISTUNG (KW)
0
2
4
5
8
10
12
14
16
18
20
22
24
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
MITTL. WINDGESCHW. WAEHREND DES ANLAGENBETRIEBES- 7.2M/S
WINDGESCHWINDIGKEIT (M/S)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
GKSS-VERSUCHSFELD PELLWORM
MAN
KAN.-DEUTSCHE MESSKAMPAGNE
MAI 83

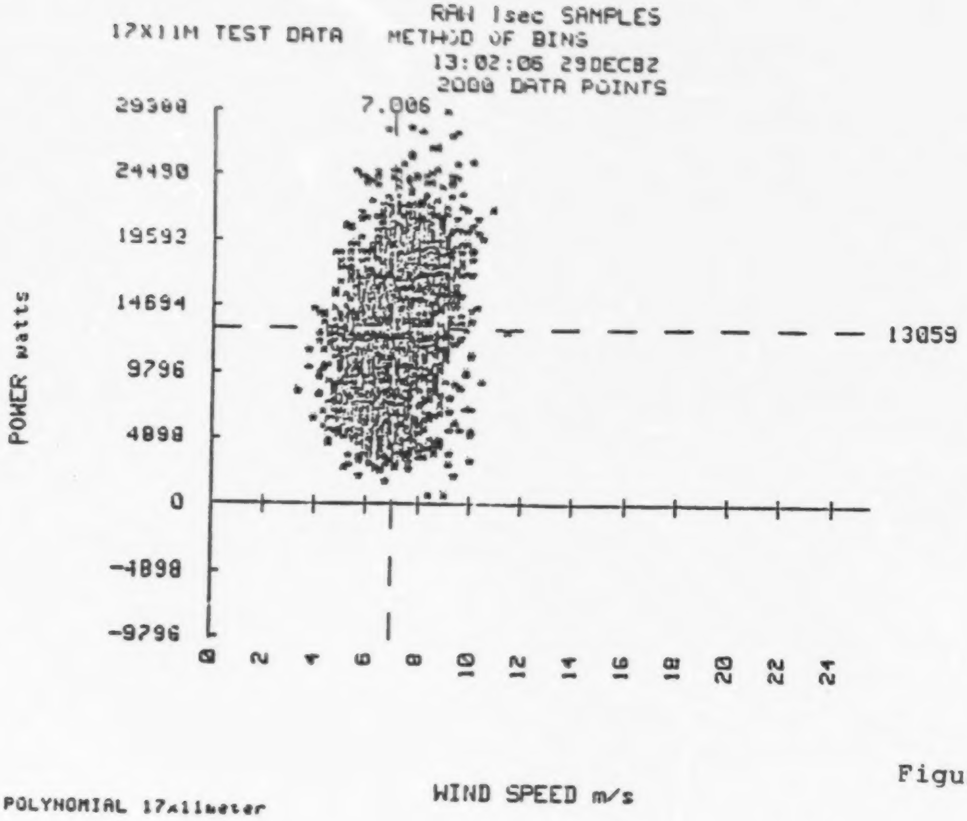
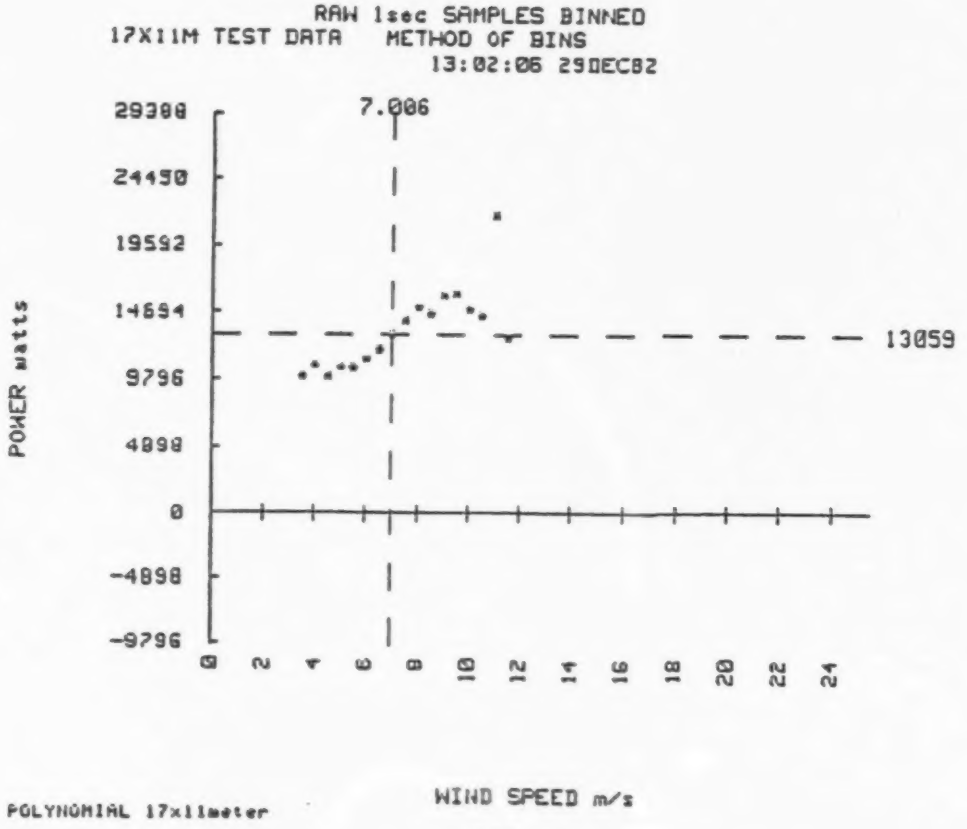

RAW 1sec SAMPLES
17X11M TEST DATA METHOD OF BINS
13:02:06 29DEC82
2000 DATA POINTS
7.006
29388
24490
19592
14694
9796
4898
0
-4898
-9796
13059
POWER watts
0
2
4
6
8
10
12
14
16
18
20
22
24
WIND SPEED m/s
POLYNOMIAL 17x11meter

Figure: 3


RAW 1sec SAMPLES BINNED
17X11M TEST DATA METHOD OF BINS
13:02:06 29DEC82
7.006
29388
24450
19592
14694
9796
4898
0
-4898
-9796
13059
POWER watts
0
2
4
6
8
10
12
14
16
18
20
22
24
WIND SPEED m/s
POLYNOMIAL 17x11meter

```
17x11meter VAWT TEST DATA

START TIME                        13:02:06 29DEC82
STOP TIME                         14:30:00 29DEC82

AVERAGE TEMPERATURE                275.65 `Kelvin
AVERAGE PRESSURE                   774.06 mmHg
AIR DENSITY                        .99082

AVERAGE WIND SPEED                 7.002 m/s
RECURSIVE STD. DEV. (wind)         1.2222 m/s
WIND DIRECTION                    300

TURBULENCE INTENSITY               .17454

AVERAGE POWER                      12933 watts
RECURSIVE STD. DEV. (power)        5044.9 watts

ENERGY AVAILABLE                   12.542  Kwh
ENERGY ACTUAL                      7.183  Kwh
EFFICIENCY                         57.27  %

NUMBER OF OBS                      1999
SAMPLING INTERVAL                  1  sec


----------------------------------------------------------------
WIND      MEAN                    STANDARD              BIN
SPEED     POWER                   DEVIATION             COUNT

* 3.5      9994.4                  5869.8                3
* 4        10804                   4577.4                10
* 4.5      10010                   2080.7                45
* 5        10679                   1942.8                71
  5.5      10607                   1325.5                212
  6        11215                   967.43                198
  6.5      11882                   796.71                346
  7        12996                   1048.4                249
  7.5      13982                   1137.5                325
  8        14953                   1086.1                232
  8.5      14495                   1392.7                124
  9        15820                   1116.9                120
* 9.5      15949                   4137.3                34
* 10       14905                   4021.6                26
* 10.5     14308                   13890                 2
* 11       21712                   0                     1
* 11.5     12752                   0                     1

Data flagged with `*' contains less than 5% of the observations
```

Figure: 4

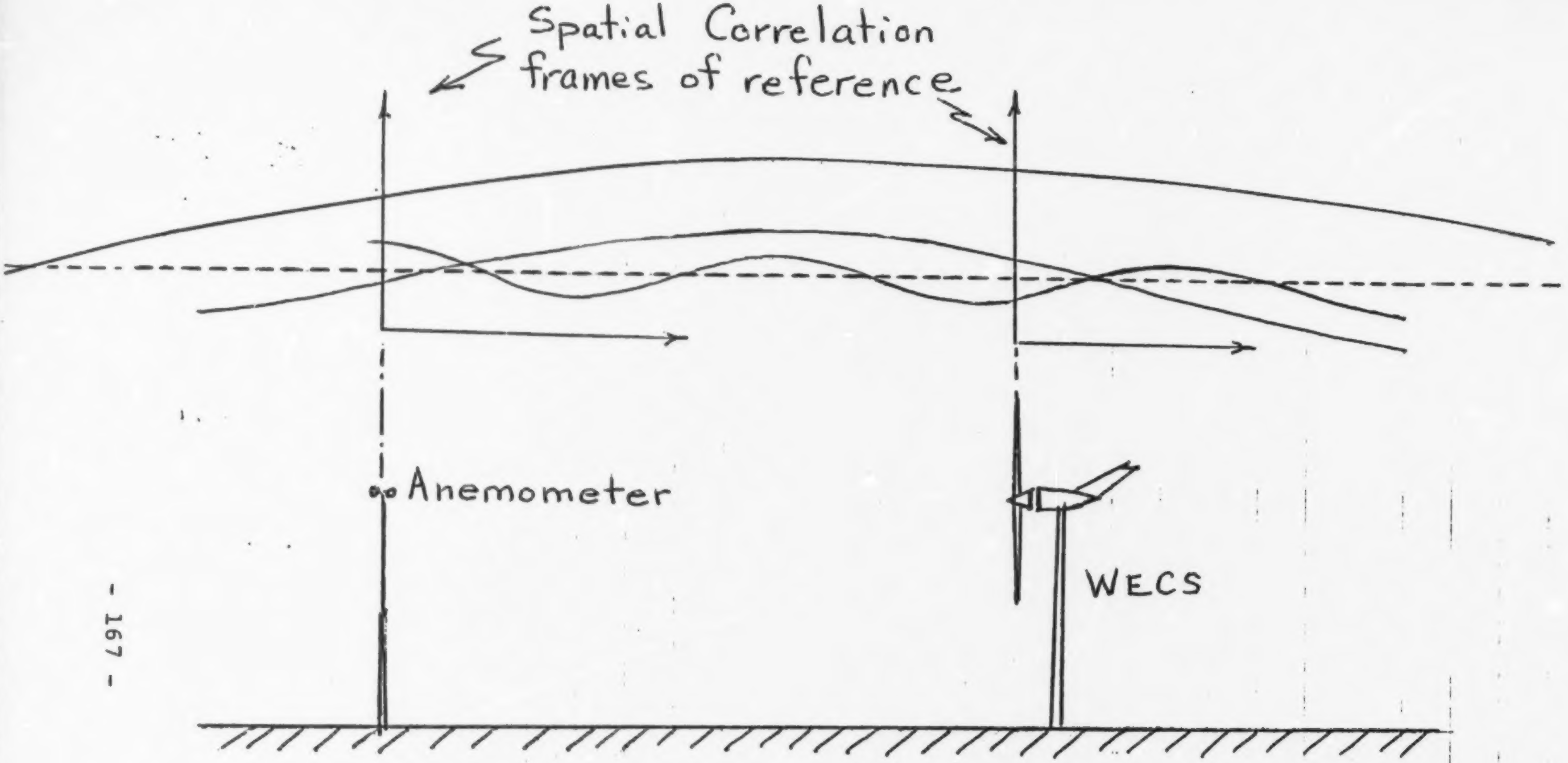

Spatial Correlation frames of reference
Anemometer
WECS

Figure: 5 INFLUENCE OF VARIOUS WAVELENGTHS OF TURBULENCE ON CORRELATION OF POWER VERSUS WINDSPEED MEASUREMENTS

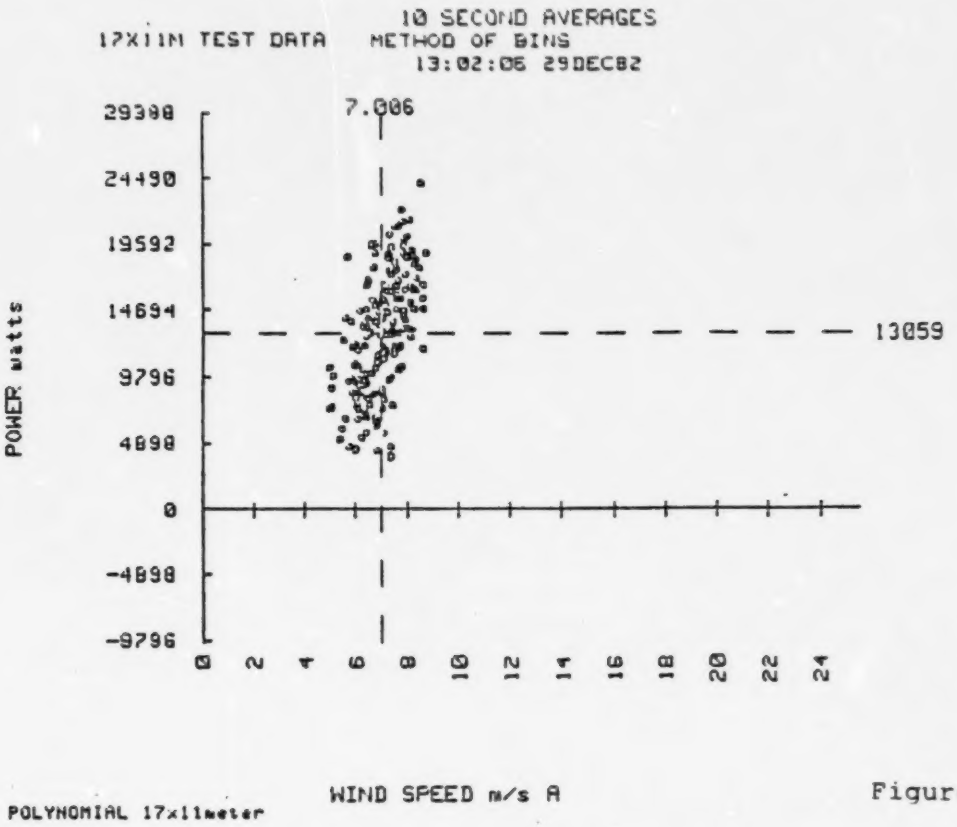
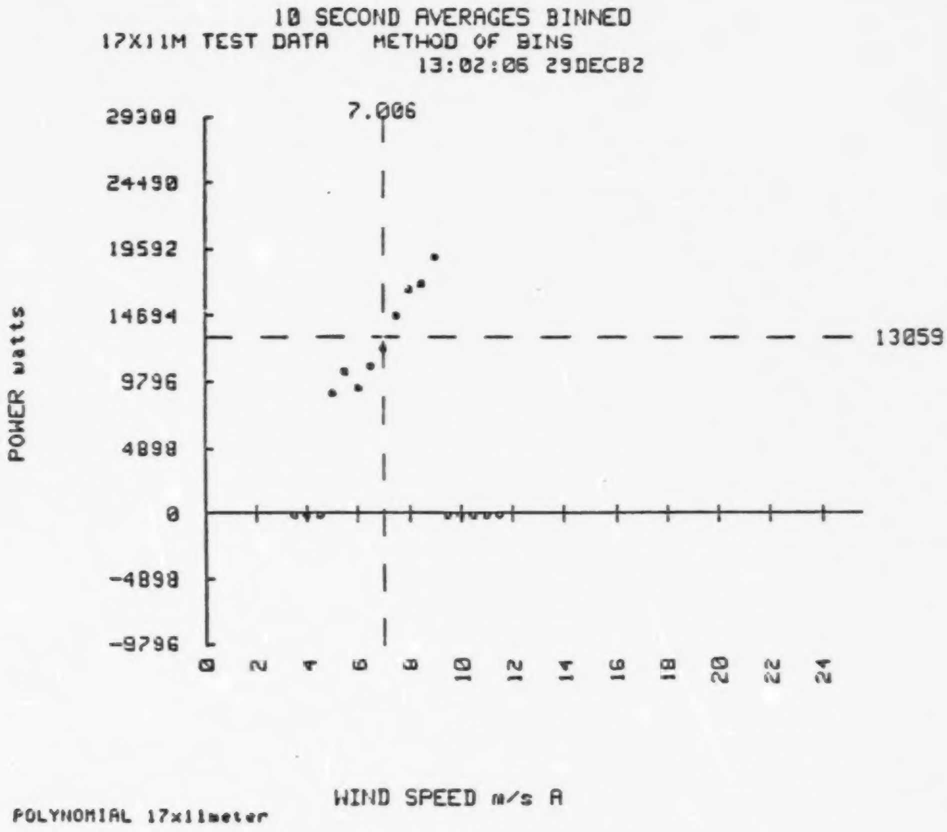

10 SECOND AVERAGES
17X11M TEST DATA
METHOD OF BINS
13:02:06 29DEC82
7.006
29388
24490
19592
14694
9796
4898
0
-4898
-9796
13059
POWER watts
0
2
4
6
8
10
12
14
16
18
20
22
24
WIND SPEED m/s A
POLYNOMIAL 17x11meter

Figure: 6


10 SECOND AVERAGES BINNED
17X11M TEST DATA
METHOD OF BINS
13:02:06 29DEC82
7.006
29388
24490
19592
14694
9796
4898
0
-4898
-9796
13059
POWER watts
0
2
4
6
8
10
12
14
16
18
20
22
24
WIND SPEED m/s A
POLYNOMIAL 17x11meter

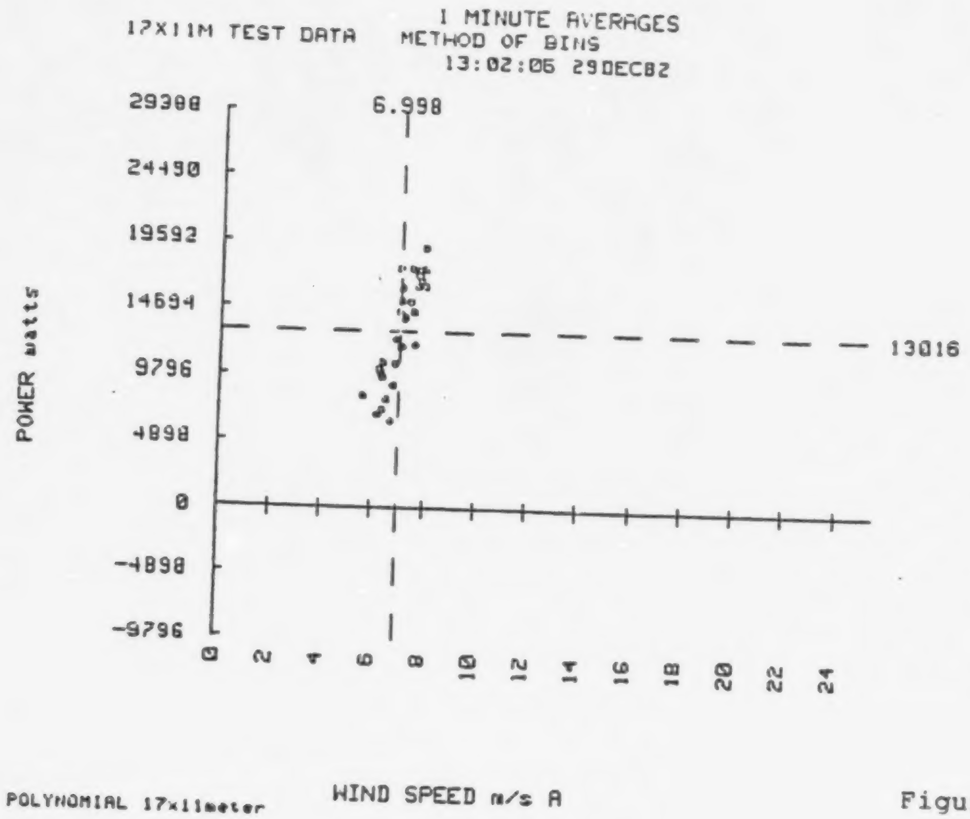
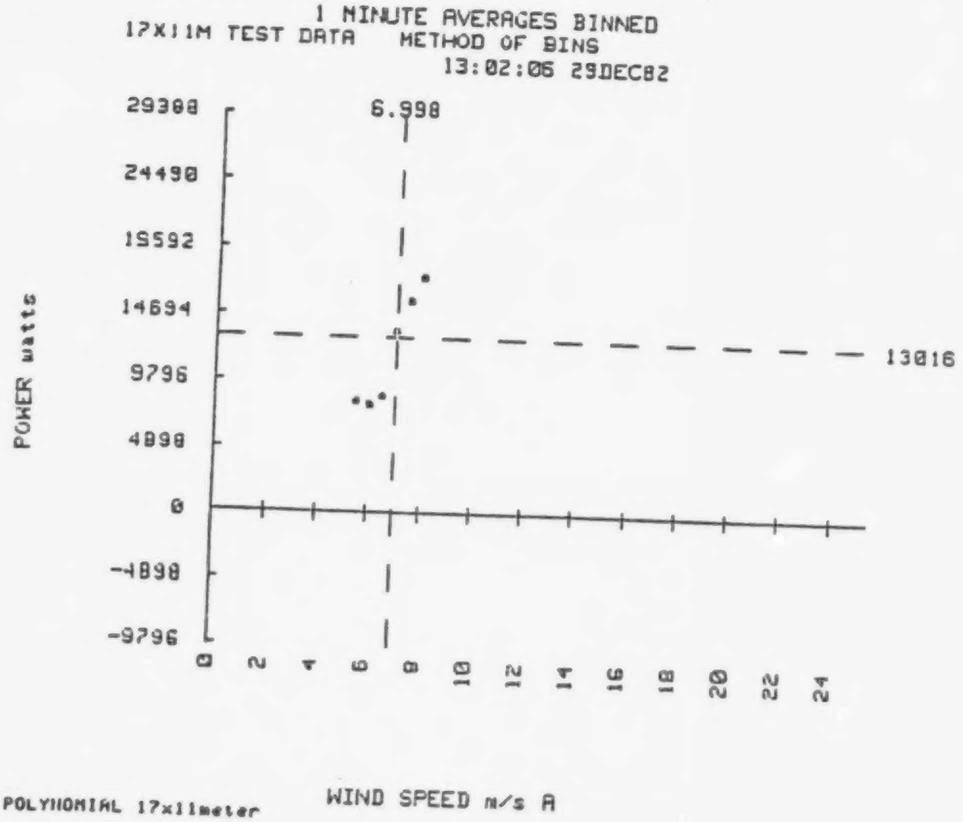

1 MINUTE AVERAGES
17X11M TEST DATA METHOD OF BINS
13:02:06 29DEC82
29388
24490
19592
14694
9796
4898
0
-4898
-9796
6.998
13016
POWER watts
0
2
4
6
8
10
12
14
16
18
20
22
24
POLYNOMIAL 17x11meter
WIND SPEED m/s A

Figure: 7


1 MINUTE AVERAGES BINNED
17X11M TEST DATA METHOD OF BINS
13:02:06 29DEC82
29388
24490
19592
14694
9796
4898
0
-4898
-9796
6.998
13016
POWER watts
0
2
4
6
8
10
12
14
16
18
20
22
24
POLYNOMIAL 17x11meter
WIND SPEED m/s A

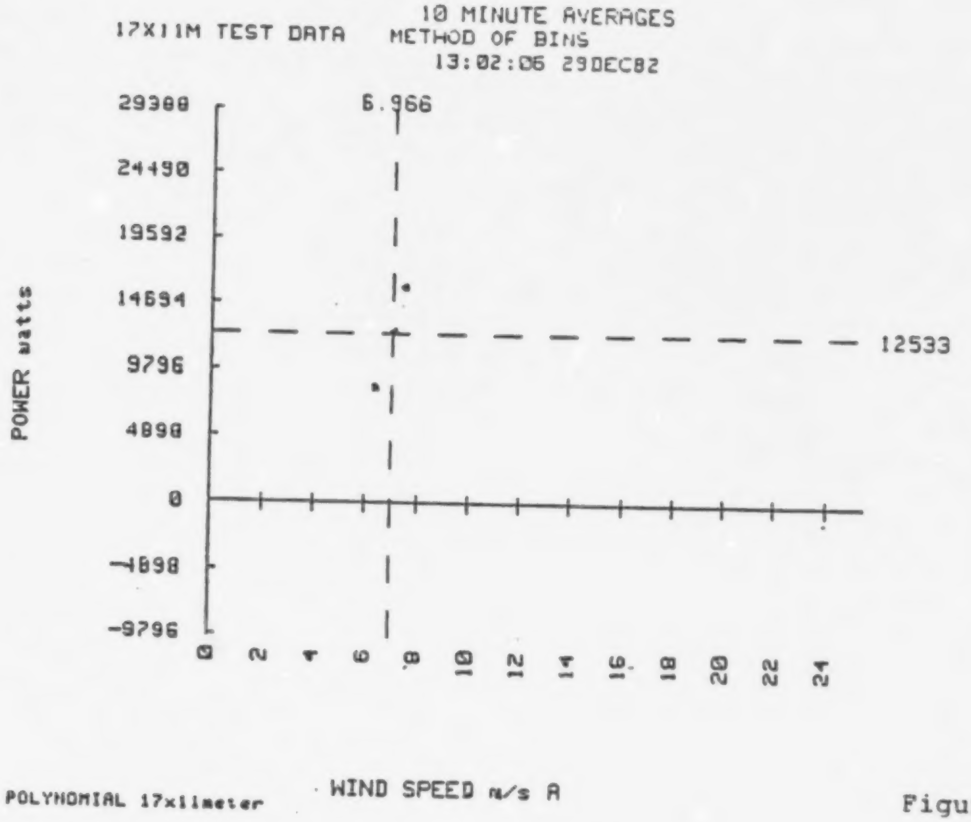
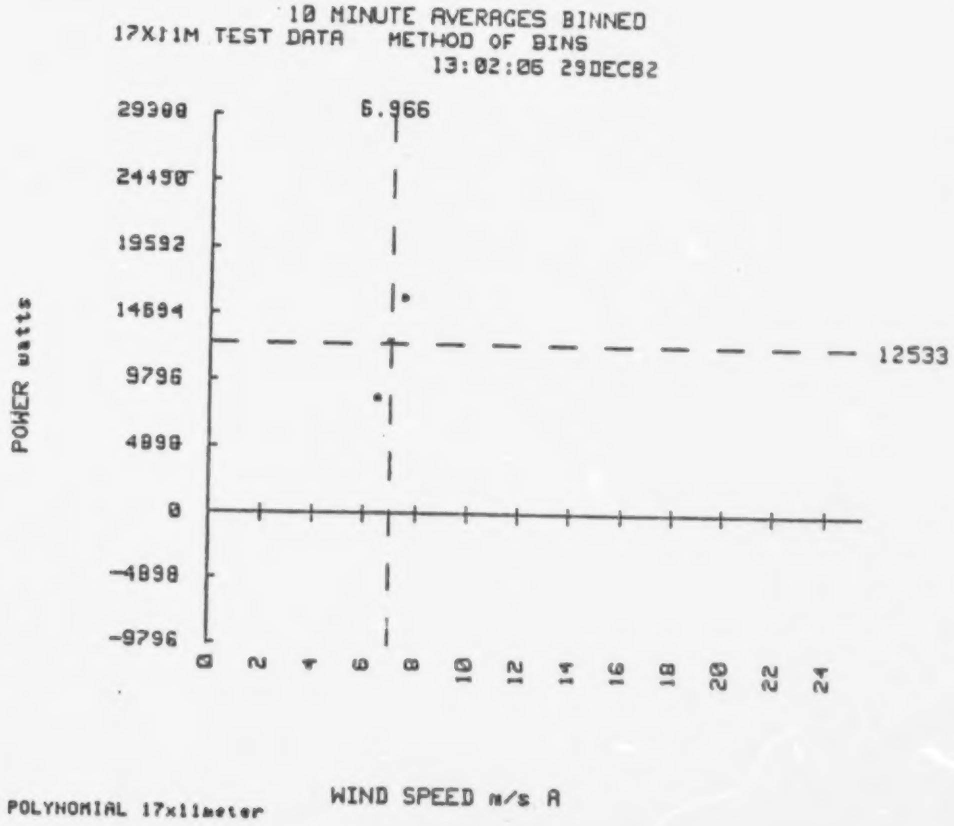

10 MINUTE AVERAGES
17X11M TEST DATA METHOD OF BINS
13:02:06 29DEC82
29388
24490
19592
14694
9796
4898
0
-4898
-9796
6.966
12533
POWER watts
0 2 4 6 8 10 12 14 16 18 20 22 24
POLYNOMIAL 17x11meter
WIND SPEED m/s A

Figure: 8


10 MINUTE AVERAGES BINNED
17X11M TEST DATA METHOD OF BINS
13:02:06 29DEC82
29388
24490
19592
14694
9796
4898
0
-4898
-9796
6.966
12533
POWER watts
0 2 4 6 8 10 12 14 16 18 20 22 24
POLYNOMIAL 17x11meter
WIND SPEED m/s A

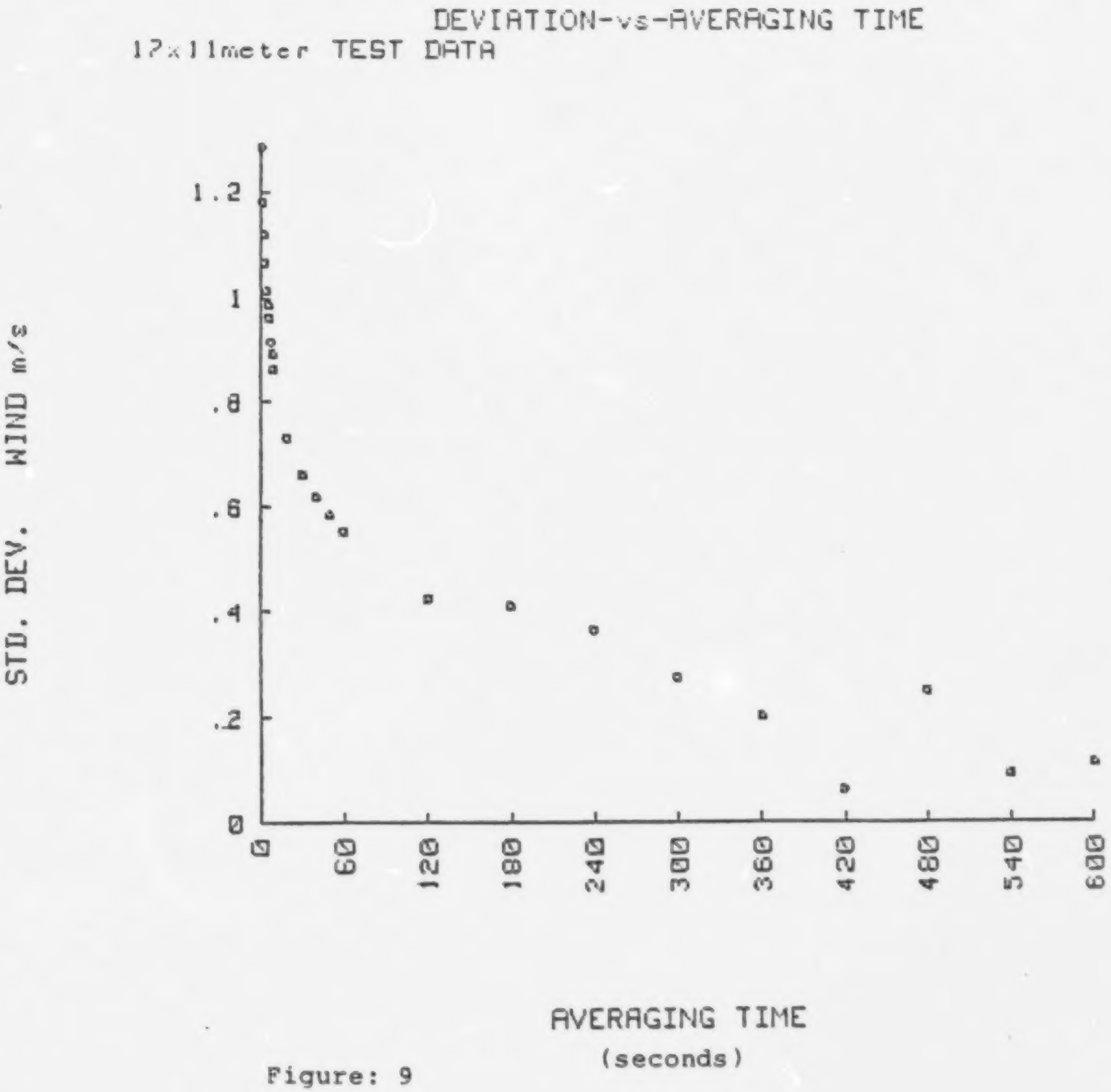

DEVIATION-vs-AVERAGING TIME
12x11meter TEST DATA
STD. DEV. WIND m/s
1.2
1
.8
.6
.4
.2
0
0
60
120
180
240
300
360
420
480
540
600
AVERAGING TIME
(seconds)

Figure: 9

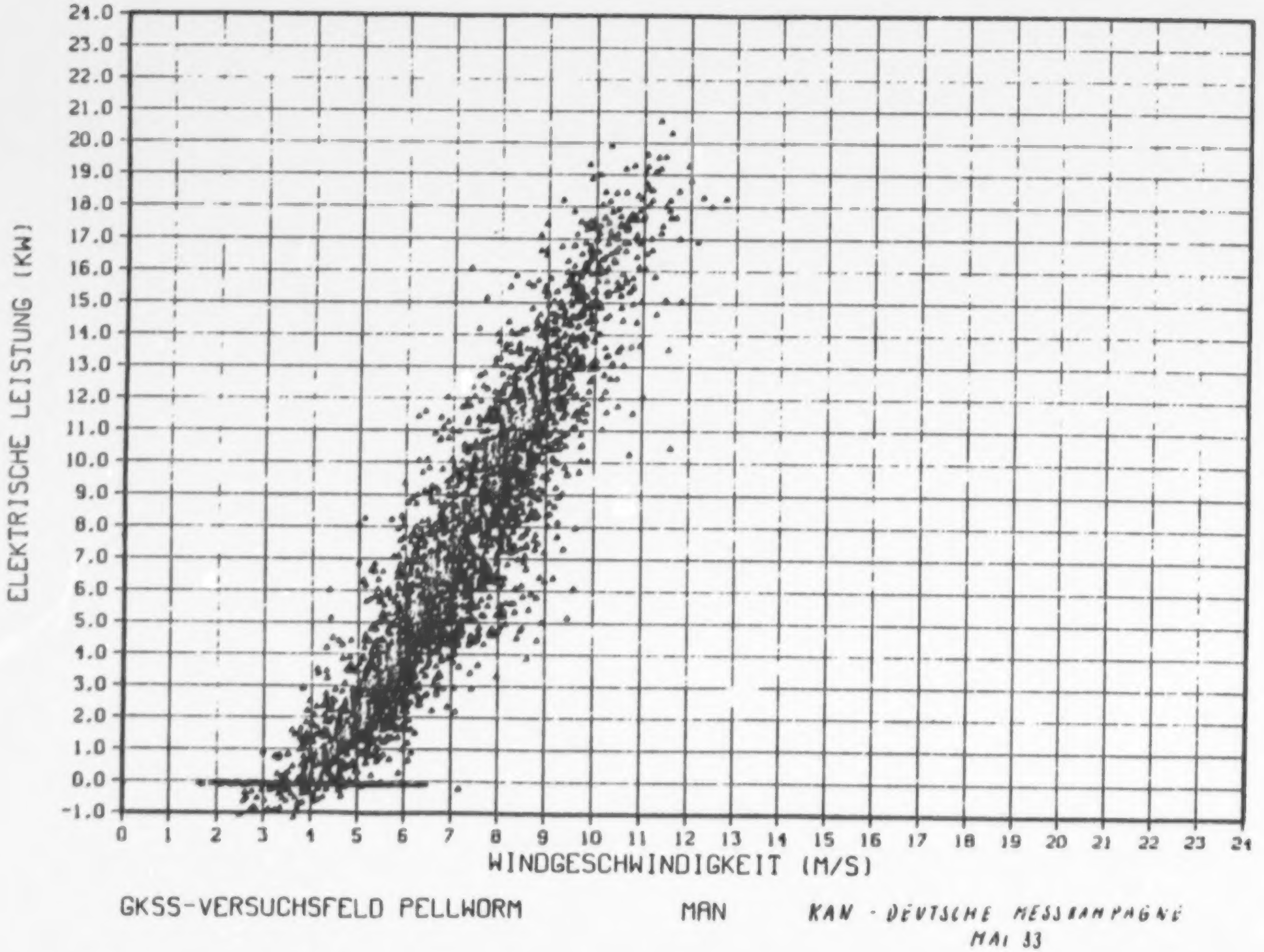


Figure: 10 MAN power curve with telescoping anemometer reference, 3° pitch, 10-s averages

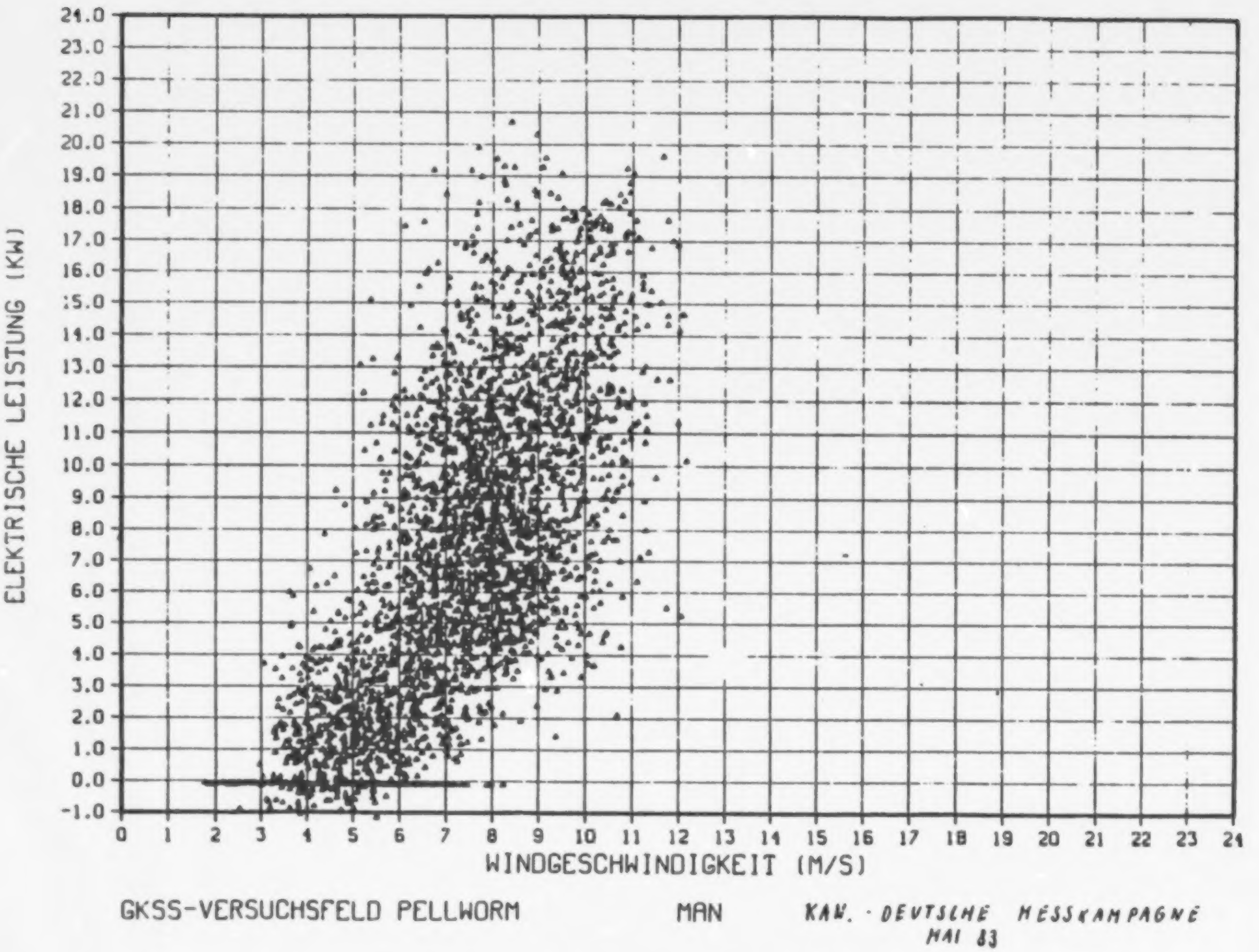
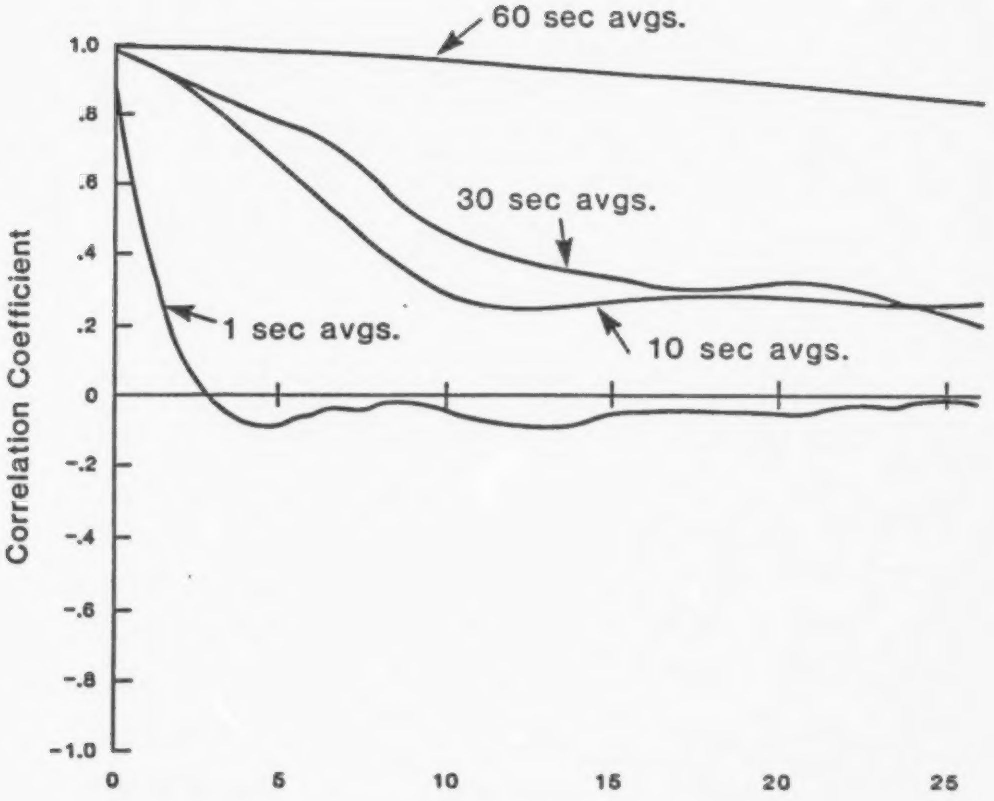


Figure: 11 **MAN power curve with 45-m mettower anemometer reference, 3° pitch, 10-s averages**

Figure: 12

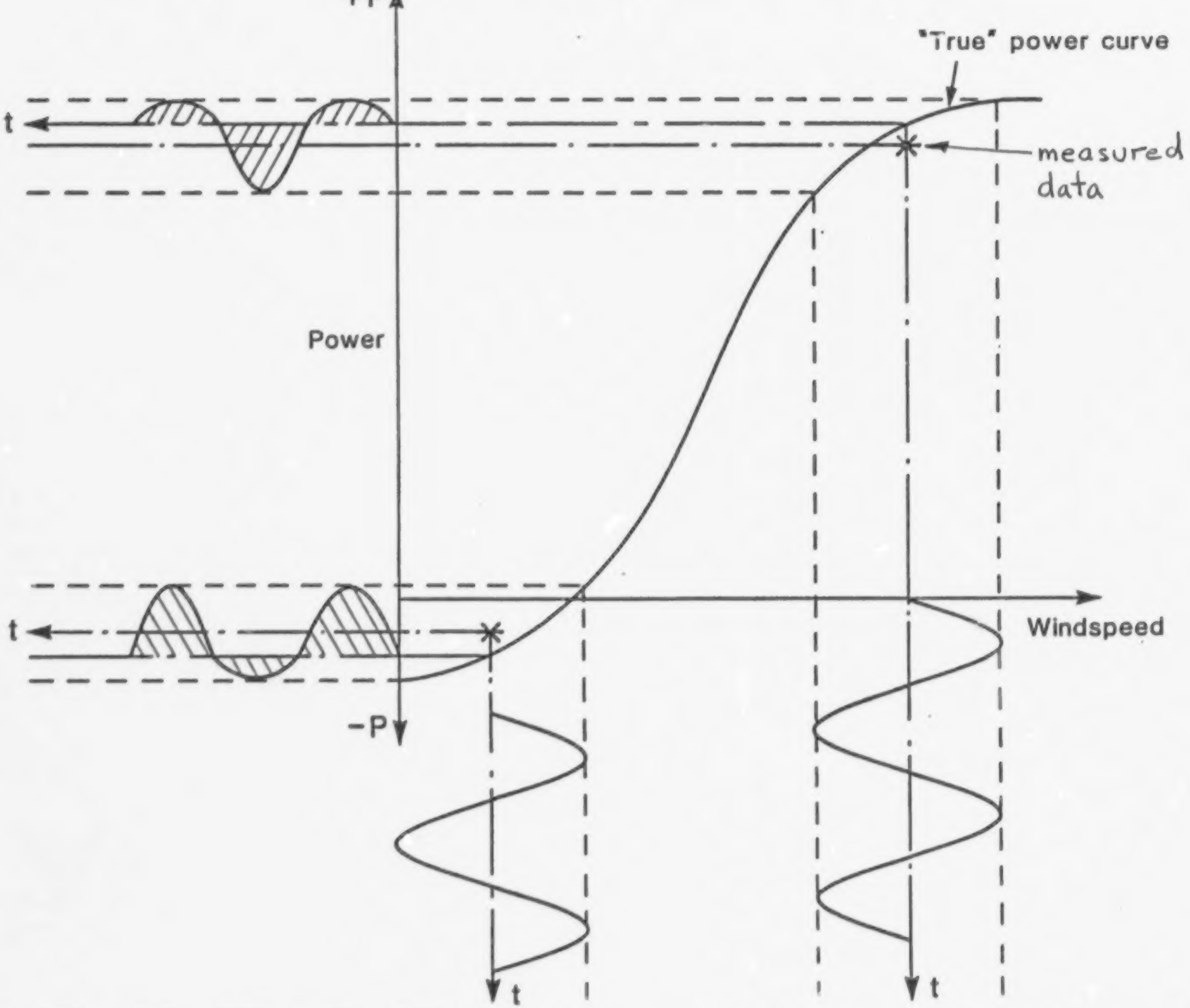


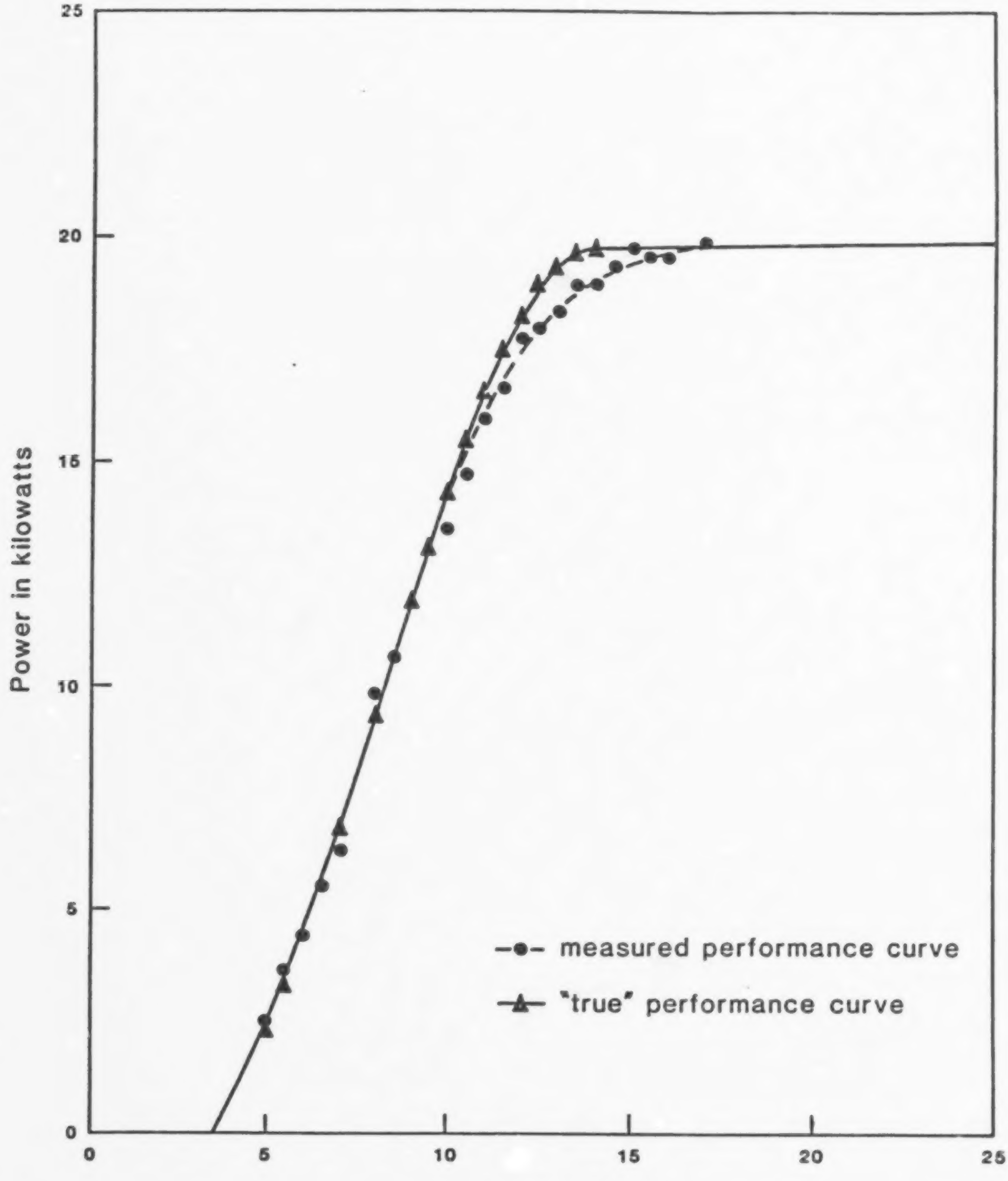
Rotor Diameter(s) to Anemometer

Typical correlation of WECS power output versus windspeed as a function of averaging interval and rotor to anemometer spacing

Figure: 13

Effect of turbulence and WECS non-linearity on performance measurements


+P
"True" power curve
t
measured data
Power
t
Windspeed
-P
t
t

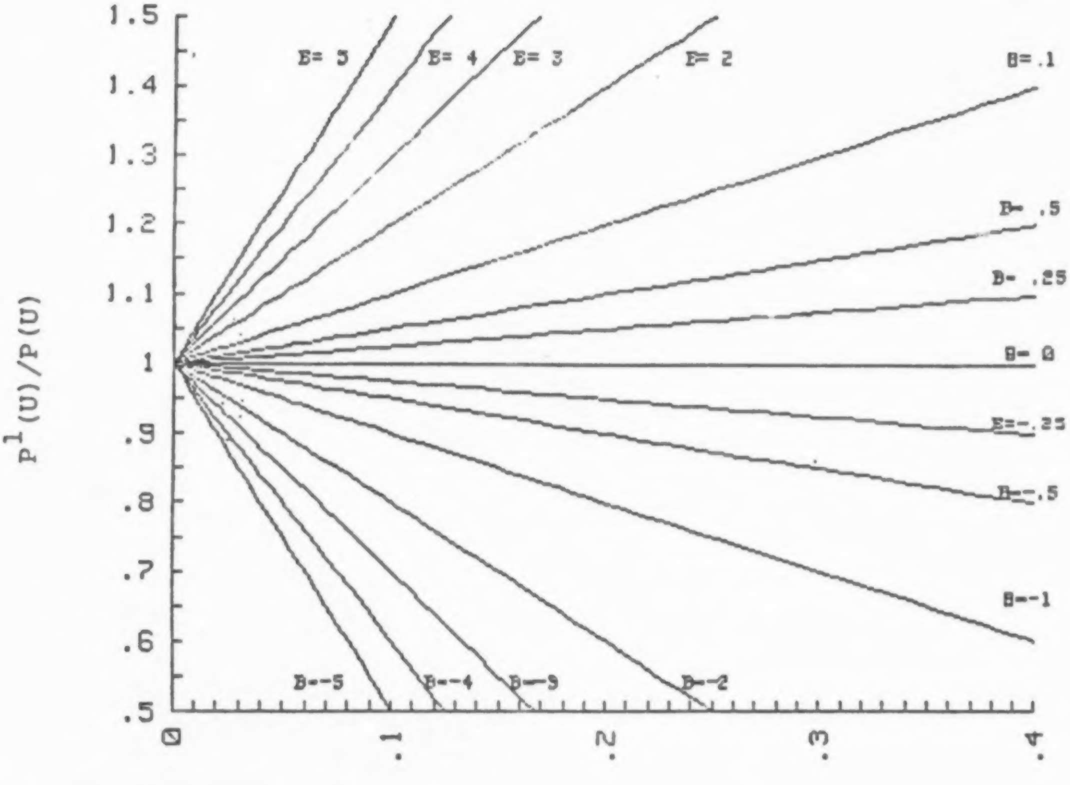


Performance Curve of Simulated WECS
Versus
"True" Performance Curve

Figure: 14

Figure: 15

BIAS DUE TO TURBULENCE



$$B = \frac{3 + \frac{b_1}{b_2\overline{U}}}{1 + \frac{b_1}{b_2\overline{U}} + \frac{b_0}{b_2\overline{U}^2} + \frac{a_0}{b_2\overline{U}^3}}$$

Figure: 16

CORRECTION OF POWER CURVE MEASUREMENTS FOR TURBULENCE & NON-LINEARITY EFFECTS:

'TRUE' POWER CURVE:

$$P(u) = a_0 + b_0 u + b_1 u^2 + b_2 u^3$$

MEASURED POWER CURVE:

$$P'(u) = a_0' + b_0' u + b_1' u^2 + b_2' u^3$$

CORRECTIONS:

$$a_0 = a_0' \quad \& \quad b_0 = b_0'$$

$$b_1 = b_1' \big/ 1 + (T.I.)^2 \cdot k$$

$$b_2 = b_2' \big/ 1 + 3(T.I.)^2 \cdot k$$

Figure: 17

- MINIMUM DATA BASE REQUIREMENTS
- CONFIDENCE INTERVALS

  AND
- ESTIMATES OF "TRUE" BIN AVERAGES OF POWER

MINIMUM DATA BASE RECOMMENDED

IEA STANDARD:

10, 10 MINUTE AVERAGES PER BIN

3000, 10 MINUTE AVERAGES FOR ALL BINS

AWEA STANDARD:

40, 1 MINUTE AVERAGES PER BIN BELOW 12 m/s

20, 1 MINUTE AVERAGES PER BIN FOR 12-15 m/s

10, 1 MINUTE AVERAGES ABOVE 15 m/s.

Figure: 18

ESTIMATES OF 'TRUE' BIN AVERAGES OF POWER

$$\text{'TRUE'} \Rightarrow u_x = \lim_{N \to \infty} \frac{1}{N} \sum_{1}^{N} x_i$$

$$\text{ESTIMATE} \Rightarrow \bar{x} = \frac{1}{N} \sum_{1}^{N} x_i$$

WE CAN HOWEVER MAKE A CONFIDENCE STATEMENT ABOUT THE ESTIMATE $\bar{x}$ RELATIVE TO THE TRUE MEAN u_x :

Figure: 19

CONFIDENCE INTERVAL

CONSIDER AN INTERVAL ABOUT THE ESTIMATE WITHIN WHICH WE ARE P% CERTAIN THAT THE ACTUAL MEAN OF THE BIN IS CONTAINED:

$$\left[\bar{x} - \frac{S_{x_i} t_{N-1;\alpha/2}}{\sqrt{N}}\right] \le u_x < \left[\bar{x} + \frac{S_{x_i} t_{N-1;\alpha/2}}{\sqrt{N}}\right]$$

S_{x_i} = STANDARD DEVIATION OF x_i SAMPLES

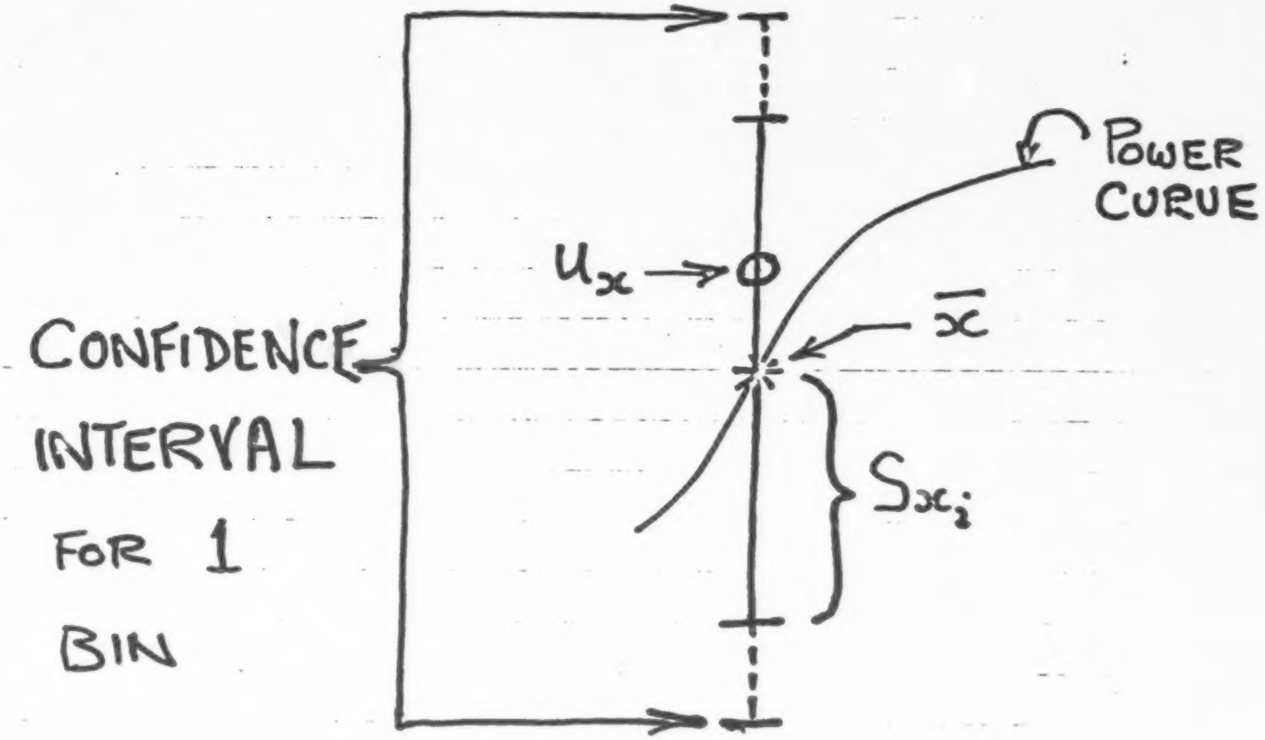
t = t STATISTIC OF THE STUDENT'S DISTRIBUTION

$\alpha = 1 - \frac{P}{100}$

$N > 1$

INTERPRETATION

Figure: 20



CONFIDENCE INTERVAL FOR 1 BIN
u_x
$\bar{x}$
S_{x_i}
POWER CURVE

Figure: 21

IT MAY BE DESIRED THAT P% CONFIDENCE IN THE PERFORMANCE CURVE ON A BIN-BY-BIN BASIS BE KEPT WITHIN ±D% OF THE SAMPLE MEAN,

THEN:

$$S_{x_i} \leq \left(\frac{D}{100}\right)\bar{x}\,\frac{\sqrt{N}}{t_{N-1;\alpha/2}}$$

THIS THEN IS THE CRITERIA PROPOSED FOR ESTABLISHING A MINIMUM DATA BASE FOR ALL BINS.

Figure: 22

EXAMPLE :

$N = 10$, $P = 99\%$, $D = \pm 2.5\%$

$\bar{x} = 14{,}710$ watts for 7.5 M/S BIN

$Sx_i = 858$ watts for 10, 10 MINUTE AVEROGES

YIELDS :

$$\alpha = 1 - \frac{P}{100} = 0.01 \longrightarrow \frac{\alpha}{2} = 0.005$$

$t_{N-1;\alpha/2}$ from t statistic table $= 3.25$

$$Sx_1 \leq \left(\frac{2.5}{100}\right) 14{,}710 \, \frac{\sqrt{10}}{3.25}$$

or $Sx_i \leq 358$ watts

TO MEET THE REQUIREMENTS.

Figure: 23

IF N IS INCREASED TO 40, 10 MIN. AVERAGES;

$$t_{N-1;\alpha/2} = 2.7$$

AND

$$S_{x_i} \leq \left(\frac{2.5}{100}\right) 14{,}710 \; \frac{\sqrt{40}}{2.7}$$

$$\leq 861 \text{ watts}$$

WHICH MEETS THE NEEDS OF THE MEASUREMENTS.

ATLANTIC WIND TEST SITE CURRENT PROJECTS
DECEMBER, 1984

Hal Arthurs
Atlantic Wind Test Site
R.R. #4, Tignish
P.E.I. C0B 2B0

ABSTRACT

The Atlantic Wind Test Site (AWTS) is a national facility to facilitate research, development, testing and demonstration of wind energy technology and equipment in Canada. Since its opening in July 1980, the AWTS has worked on wind energy technology projects sponsored by both private and government clients and the National Reserch Council (NRC). A listing and description of current projects is given.

1. INTRODUCTION

The Atlantic Wind Test Site (AWTS) at North Cape, Prince Edward Island has been created by the Governments of Prince Edward Island and Canada to facilitate research, development, testing and demonstration of wind energy technology and equipment in Canada. The laboratory facilities are located in a harsh but typical coastal environment in the Gulf of St. Lawrence where the effect of a full range of climatological and meteorological conditions on wind energy conversion systems can be observed and measured. A high speed microprocessor based computerized data acquisition and control system is used to carry out investigation of performance.

The AWTS was designed and developed by the Institute of Man and Resources (IMR) under the 1977 Canada-P.E.I. Agreement on Renewable Energy Development and was officially opened for business in July 1980. The facility is managed by IMR under the terms of a ten year operating agreement with the National Research Council.

Resource Ventures Incorporated, a wholly owned subsidiary of the Institute of Man and Resources, provides staff and management to operate the site as the agent for IMR.

2. FUNDING

The AWTS obtains operating funds from both paying clients and users of the site's resources and from the National Research Council, Energy Division through a contribution agreement. The contribution agreement provides a contribution of up to \$200,000/year to offset operating costs. The agreement has a ten year term commencing in 1981 and is managed by five directors, three named by the NRC and two by IMR. The directors meet quarterly to review operations and to provide guidance for new development and activity.

3. PROJECTS

The projects listed below are organized in chronological order, more or less. Project numbers are for internal AWTS reference and should be referenced when corresponding or requesting information.

3.1 Performance and Reliability of a 1 kW Bergey Wind Turbine (Project 29.07)

Sponsor: Internal AWTS Study
Status: Report available on original study - Testing continuing
Summary: A 1 kW Bergey wind turbine has been under test for several years. It was originally designed as a battery charger to provide emergency power to an aquaculture aeration system. Reliability of the machine has been evaluated and a report completed describing failure of the machine's original aluminum blades.

The manufacturer has since changed the material and configuration of the blades and the machine is presently being connected to the utility grid using a Gemini inverter to provide long term reliability and performance data.

3.2 Performance Evaluation of a DAF Indal 9 m x 6 m, 7 kW VAWT (Project 29.02)

Sponsor: Internal AWTS Investigation
Status: Test Continuing
Summary: This machine was originally designed to supply hydraulically generated heat energy to a greenhouse application. After installation at the AWTS the drive train was modified to drive an induction generator connected to the utility grid. (A report is available on this modification.)

In September, 1983, the machine suffered a blade failure above the upper strut. Analysis showed fatigue failure initiated by a nick on the trailing edge at the strut and subsequent propagation forward. A used set of blades was obtained and installed using a modified strut connection. Testing of the machine is continuing.

3.3 Anemometer Comparison Project (Project 50.09)

Sponsor: Department of the Environment, Atmospheric Environment Service
Status: Installation complete, data acquisition in progress.
Summary: The performance of 16 anemometers are being compared over a period of 12 months to determine performance and reliability. The performance of the units is being compared with

AES standard units over a wide range of environmental conditions. AWTS is installing and monitoring the units and has designed and assembled signal conditioning circuits to interface with the data acquisition system. Software to AES specification to provide continuous data acquisition, reduction and storage has also been produced.

Final test results will, among other things, compare accuracy, total cost and availability of each of the units.

3.4 Small Wind Power Systems Testing (50.30 & 50.31)

Sponsor: Ontario Ministry of Energy (OME)
Status: Tests in progress
Summary: OME has implemented a program to encourage use of wind and other renewable resources by remote users of conventional sources in Ontario. The goal is to have 5% of Ontario's needs of 1995 met by renewable energies. As part of a project to install a small WECS in a remote location in Ontario OME has obtained two small machines which are presently being tested at the AWTS to determine performance and reliability data. The two machines under test are;

I) Wellington Windpower is a 3 kW HAWT. The machine has a three bladed, four meter diameter rotor with full pitch control. It is an upwind unit mounted on a 13 m tower. Yaw is controlled by a fan tail rotor which can be manually deflected from the ground to enable shutdown. The variable 3 phase voltage output is connected to a 3 kW resistive heating load.

II) Extrawatt RX14.3 is a downwind machine with a three bladed 4.3 m diameter blade. It has automatic pitch adjustment coupled with a coning system for overspeed control. Installed on a 9 m tower, it has a self-excited synchronous generator which is connected to a resistive heater load.

If test results indicate acceptable reliability, one or both of these machines will be selected for demonstration at a remote site in Ontario.

3.5 Northwind L-916 Performance Testing (Project 50.08)

Sponsor: Health and Welfare Canada (H&WC) Status: Test in progress Summary: H&WC have purchased a L-916 Northwind HAWT for installation at Hall Beach, N.W.T. The 16 kW machine is under test at AWTS to confirm performance and reliability prior to installation at Hall Beach. The machine has a two bladed nine meter diameter rotor mounted on a 70 ft tower. It is a downwind machine with passive pitch control. The single phase output is connected to the utility grid.

3.6 Aquilo (Project 50.22)

Sponsor: National Research Council

Status: Testing continuing
Summary: The AWTS is presently testing a DAF Indal series 6400 VAWT purchased by NRC. It is rated at 522 kW in a 42.5 mph wind. The rotor, 36.6 m (120 ft) high and 24.4 m (80 ft) across rotates at 45 rpm and drives two 350 HP induction motors through a 16:1 spur gear single mesh speed increaser.

The rotor and drive train are fully instrumented to obtain dynamic structural data.

3.7 Adecon (Project 50.12)

Sponsor: National Research Council
Status: Erection in progress
Summary: NRC has provided funding for development and construction of a free standing 125 kW VAWT by Adecon Energy Systems. The prototype is presently being erected at the AWTS and will be tested to determine operational characteristics.

The rotor 25.5 m (84 ft) x 17 m (56 ft) sits 13 m (43 ft) above ground level and is supported by a lattice work of angle sections. The lightweight aluminum blades rotate at 45 rpm and are connected through a speed increasing transmission to an induction motor.

Rotor and drive train will be fully instrumented to provide data necessary for performance evaluation.

4. CONCLUSIONS

Since its establishment, the AWTS has becomes a major resource able to assist and encourage the Canadian WECS industry. During this period the site has obtained much of the equipment and developed many of the skills and much of the expertise necessary to install and test WECS effectively and efficiently. Many projects have been successfully completed and several new and exciting projects are in progress. Manufacturers and users of new WECS technology have recognized the need for thorough testing and evaluation of performance and reliability before committing themselves to the major capital outlays and risk involved in producing or purchasing machines. The AWTS is able to respond to this need and to react quickly to requests for information and assistance from the WECS industry.

For information regarding terms and conditions of site use, rates and fees for professional assistance and consulting and for quotes and estimates for testing work, please contact the AWTS or Resource Ventures Inc., 49 Pownal St., Charlottetown, P.E.I.

Q. Can you enlarge on the term 'passive pitch control' please?

A. (Arthur) I could probably elaborate on the data acquisition system a little better. I am not really familiar with the passive pitch control.

A. (Lodge) I'll field that one if you like. I'll just put on my other hat as an occasional visitor at the Atlantic Wind Test Site. The Northwind machine has a passive pitch control that is actuated by two methods. The overspeed loads on the rotor are balanced with centrifugal weights. Also, flatwise pressure on the blade results in a moment on the blade. This causes it to pitch out. This can occur either under conditions of overspeed on the rotor or because of conditions of high wind and stall pressures on the blade. There is also an active element to the pitch control on that machine. The rotor is loaded against a pneumatic spring. The spring is energized with an air compressor, a pneumatic ram system allows you to remotely release the pressure from the ground. The release in pressure causes the blade to go into a pitched condition at zero velocity.

INTERSOL-85

SOLAR ENERGY - THE DIVERSE SOLUTION
INTERSOL'85
JUNE 23-29, 1985
MONTREAL. QUEBEC, CANADA

Doug Lorriman, Solar Energy Society of Canada, Inc.

Introduction

It is my pleasure to invite Doug Lorriman to come up and speak to us for a minute about Intersol '85.

Presentation

Thanks very much Malcolm. I hope by this point most of you know what Intersol'85 is, but for the benefit of those who may not, it's the International Solar Energy Congress. It's held every second year and in 1985 it will be held in Montreal. It is being hosted by the Solar Energy Society of Canada and we're proud to be able to do that and we are looking forward to putting on a pretty good show.

Now, you may wonder why the Solar Energy Society of Canada is speaking to the wind energy group in this vein. Well, congruent with the Canadian thoughts on the approach to renewable energy, the Solar Energy Society of Canada decided that Intersol '85 should be broader in scope than most solar energy congresses. We should look at the broad scope of renewable energies. We know that any one discipline or any one technology, in itself, may not be a significant factor in the world energy scenes, but in totality, renewable energy has a lot to offer. We have endeavoured to bring all the renewable energy disciplines together to demonstrate this.

This is reflected in our theme which is:

"Solar Energy - the Diverse Solution".

"Diverse" meaning we are going after as many different renewable energy forms as possible.

"Solution" meaning that the theme of the conference will not just be in terms of technical and scientific presentation. Rather, taking the technology and learning how to apply it to specific solutions throughout the world.

Now, at the present time, we feel that we are in a very good position with Intersol'85. It's being held in June 1985 and we are very optimistic, those of us in the organizing committee, regarding the response that we've had.

We've had over 750 abstracts submitted for the conference. They are being reviewed now and the authours are being notified currently. A gratifying number of those papers have been submitted on wind energy topics and so I think that will be of interest to the group here.

The other part of the congress is an exhibition and we have a rather ambitious exhibition programme. The whole event is being staged in the new conference centre in downtown Montreal, the Palais des Congres, and we have the full lower floor for our exhibtition. We are happy to say that right now, still over six months out, we are committed to approximately 50 per cent of the space in the exhibition and we feel that's quite a good position to be in, at this point.

I would like to promote on two grounds.

Those of you who have an academic and technical interest in wind energy, or renewable energy in general, come to Intersol'85 to share your ideas and learn from those others who are there from around the world.

For those of you who have products, I would encourage you to display at Intersol'85 because we think there's going to be a broad international delegation and a lot of interested buyers there.

Now, let me say a couple of words to the Canadian delegation here. I'll take my Intersol'85 hat just halfway off and speak to you as a fellow member of the renewable energy commmunity.

As you know, in Canada, we have just recently had some interesting and somewhat disturbing news on the renewable energy front. All of us view this with some concern and we realize that it presents some challenges to us to show the importance of renewable energy to policy makers and decision makers. I think we are fortunate with the timing of Intersol'85 to have this unique opportunity to show to people in Ottawa that the Canadian renewable energy industry is indeed alive and vital, and that they should stand up and take notice of this. I think that a good Canadian presence at Intersol'85 would go a long way towards this, in terms of delegation, in terms of technical presentation and in terms of exhibits. I know that a number of other countries are planning some very ambitious exhibits and representations at Intersol'85. I certainly think it behooves the Canadian renewable energy industry and community to do the same.

For those of you who want more information, I have a bulletin here. I'm going to leave copies of this bulletin out on the table. You may wish to pick one up. This particular one is directed at the exposition, so those of you who are looking to exhibit may take this. It has all the information you need. Those of you who are just interested in the congress itself can pick one up. The address to obtain further information is contained herein. You can write us and we will send you registration information.

Thanks again for the opportunity. If you have any questions, I'll be happy to answer them or I'll be out in the hall afterwards. Thanks again, Malcolm.

Q. Do you have room to run a windmill?

A. Do we have room to run a windmill? We have had one, that I know of, enquiry about setting up an outdoor exhibition. There's a plaza in front of the Congress Hall. But, I don't know how windy it is because it's surrounded by buildings. Maybe that's good. In some cases buildings enhance the wind as we all know. There's a terrace on top of the convention centre in conjunction with a restaurant and coffee facilities. I don't know what size you may be thinking, but we have been approached regarding some outdoor exhibits. We are seriously considering allowing that to happen. We have to confer with some of the authorities to get the specific permission.

MALCOLM LODGE

Any more questions of Doug? If not, we will adjourn the meeting for about half an hour for a coffee and reconvene here at 4:30 sharp for the Canadian Wind Energy Association founding meeting. I urge you all to attend, we are few in numbers and we want to see as much interest and enthusiasm as this industry deserves at this meeting.

CHARTER MEETING
CANADIAN WIND ENERGY ASSOCIATION

CHARTER MEETING

CANADIAN WIND ENERGY ASSOCIATION

4:30 p.m. to 6:00 p.m.

AGENDA

1. Greetings and Introduction
2. Guest Speaker: "Benefits of a Wind Energy Association".
   Tom Gray, Executive Director,
   American Wind Energy Association
3. Presentation and Discussion of Charter Mission and Objectives
4. Presentation and Discussion of Proposed Fee Structure
5. Nominations for Charter Directors Accepted from the Floor
6. Vote for Five Charter Directors
7. Adjournment

5:00 - 8:00 p.m. Reception at Exhibit Area Lounge in Harbour Room, Salon C.

PROPOSAL TO ESTABLISH THE CANADIAN WIND ENERGY ASSOCIATION

Wind energy is on the verge of commercial realization in Canada. This project proposes to establish the Canadian Wind Energy Association, in cooperation with a Steering Committee composed of highly respected experts from industry and government. The objective of the Canadian Wind Energy Association is to enhance the industry's growth potential. Its work will be to operate a series of programmes that are designed to become self-financing.

BACKGROUND

Around the world in the last decade the wind power industry has experienced an unprecedented resurgence. This resurgence has been accompanied by widespread government and public support. In fact, it seems that in today's conservative economy, some form of government interest is necessary for the successful development of any new energy technology. The primary reason to establish the Canadian Wind Energy Association is to enhance the level of support for wind power in Canada to that enjoyed by other energy industries.

As a vehicle for the development of wind energy in Canada, DynamoGenesis Inc. has convened the "Annual Wind Energy Symposium". Every year manufacturers and users of wind power equipment have gathered at the Symposium to present papers, discuss recent developments in the industry, and organize business transactions. The Symposium has received favourable reviews from all corners of the industry and from government representatives as well. All agree that it is an essential process in furthering the interests of the wind industry as a whole.

The idea for the Canadian Wind Energy Association came out of the 1983 Symposium. A Foundation meeting was held in January, 1984 at the Ontario Ministry of Energy, Toronto, Ontario. The representatives of industry and government brought together in this meeting chose a Steering Committee to draw up the guidelines for the establishment of the Association. Amongst others, the Steering Committee includes: the Manager of Energy Ontario's Remote Power Unit, the Manager of Wind Energy Research and Development for the National Research Council, and the head of Energy, Mines and Resources' Renewable Energy Division. An initial Steering Committee meeting followed in February, 1984 at Energy, Mines and Resources, Canada, Ottawa, Ontario to coordinate the development of the Association.

Unquestionably, this represents a major step in the development of the Canadian wind industry. It is significant that manufacturers, designers, engineers, installers, investors, users and administrators are attempting to establish a single formally-constituted agency to represent the interests of the whole. The industry is now aware enough of its position in society to support an organization which represents its interests to the public.

Priorities for CANWEA would include:

- To provide fora for the exchange of technical and economic information among researchers, industrialists and potential users of wind energy, including the general public
- encouraging incentives for both industry and users
- attracting investment in mature technology
- educating the marketplace on the self-reliance and interdependence benefits of wind energy in various applications
- encouraging job creation

and - promoting export development to improve Canada's balance of payment 'situation'.

Seed money of $10,000. per year for the first two years of operation has been secured from Energy, Mines and Resources, Canada.

The better part of the projected start-up budget will be covered by:

- newsletter subscriptions
- conference fees
- memberships
- other federal, provincial and private support.

THE PROPOSED MISSION AND OBJECTIVES OF CANWEA ARE:

MISSION:

To promote and develop wind energy technology in Canada and for export, and to advance the products and services of its members in the wind energy industry.

OBJECTIVES:

1. To co-ordinate and serve the interests of the wind industry, particularly in terms of technical standards, trade information and research and development.
2. To represent the interests of the wind industry to the financial community in Canada, to thereby encourage the creation of equitable economic conditions for the industry.
3. To educate and inform the membership and the public about the economic importance and industrial benefits of using energy from the wind.
4. To represent the interests of the wind industry to governments of Canada, to thereby encourage the creation of equitable legislative and economic conditions for the industry.

EXPECTED DUTIES OF CANWEA DIRECTORS

- Elect among themselves a president, secretary and treasurer.
- Draft and ratify the By-laws:

  a) letters patent
  b) membership criteria
  c) membership categories
  d) fee schedule for membership
  e) etc.

- Ratify the objectives and mission of CANWEA
- Set up a periodic newsletter
- Discuss future 'Wind Energy Symposium'
- Establish an office or rent office services from another organization
- Gather information - utility policy, government policy, product information, etc.

Note:

In order to ensure a good start up to the newly formed 'CANWEA Board of Directors', an ex-officio representative of the Steering Committee will sit, for a short period of time, on the Board with no voting right. If one of the Steering Committee members is elected, this provision will not apply.

Rotation within the Board of Directors:

Procedures: - 5 Directors will be elected.

2 will have a 2 year term
3 will have a 1 year term

The 2 year terms will be given to the Directors who have received the largest number of votes.

All nominees' names will be posted on a blackboard or overhead with their affiliation.

Vote:

After a period of nominations from the floor, attendees will be requested to write the names of 5 persons they wish to become Directors. Ballots will be deposited in a box on the way out of the meeting room.

Counting will be done immediately by:

- M. Carpentier
- M. Chappell

Note:

The elected Directors will be contacted as soon as the counting is finalized and they will elect amongst themselves a president, secretary and treasurer.

The elected Directors will be introduced at the banquet and will sit at the Head table.

General:

The president will be responsible for directing the discussion and in keeping the meeting moving.

PROPOSED CANWEA MEMBERSHIP STRUCTURE

TYPE OF MEMBERSHIP	ANNUAL DUES	VOTING ELIGIBILITY FOR DIRECTORS AND BYLAWS	ELIGIBLE TO BE ELECTED AS DIRECTOR ?	MEMBERSHIP SERVICES
Individual	$30	NO	NO	newsletter each 1/4
Student	$10	NO	NO	newsletter each 1/4
Associate	$300	1 vote	YES	newsletter/ commcl info
Corporate	$1000	3 votes	YES	newsletter/ commcl info

CHARTER MEETING
CANADIAN WIND ENERGY ASSOCIATION

Fred Schwartz, Chairman
Ontario Ministry of Energy

Introduction

"Good Evening". The horizon out there is getting greyer and greyer. Now, I ask you to recognize the convening of the Charter Meeting of the Canadian Wind Energy Association.

We're going to, in just a few moments, pass over chairmanship of this meeting to Fred Schwartz. Fred has been one of the members of the Steering Committee that has been meeting off and on for the last nine months or so to organize the formation of a Canadian Wind Energy Association. Fred, until very recently, was Manager of the Remote Power Group of the Ontario Ministry of Energy and has been in that position for a few years. During that period he has been involved in a host of renewable energy projects. Several of these were wind energy R & D and demonstration projects in places as far apart as Sudbury, Winisk and the Atlantic Wind Test Site. It's always a pleasure for me to work with Fred on projects and I'm going to miss not having him involved in the renewable energy area. He tells me now he's in charge of consumer and residential energy conservation activities. So, I'll have to see what I can do to get involved with him again someday. It's a pleasure to introduce to you your chairman for this meeting, Fred Schwartz.

CHARTER MEETING 'IN SESSION'

Thanks very much, Malcolm. It's really nice to be here, This is the second of the symposia that I've attended.

Really what I wanted to do was just welcome you to this Charter Meeting. I'd like to keep the thing moving along fairly rapidly so we can perhaps even finish up a little bit earlier than we intended to give you a bit of free time before the banquet.

I should note at this point that, contrary to what it says on your agenda, the bar is not opening at 5:00. We've held it closed until this meeting is closed, so that we may hold a few more people with us for a little longer.

The Genesis of this meeting, the reason that we're having this meeting, started a little over a year ago at the Sixth Symposium.

We got a really good reaction, but afterwards we got out of the thing saying: "Well you know, what now? We can keep generating symposia on a one-off sort of basis, but what does that do?"

We felt that there should be a continuing presence for wind energy issues in Canada. However, we felt that there presently wasn't one.

There were a variety of governments that were working fairly hard on it. The federal government through EMR and the National Research Council. Ontario, Alberta, and B.C. were doing their own things. Quebec was doing their own things. But we felt that there was not a common forum really for discussion and promotion of wind energy activities.

So, we came up with the idea of the formation of a Canadian Wind Energy Association. A variety of different individuals and agencies expressed interest. We formed what we think is, really loosely, called a Steering Committee. We had a variety of meetings. Everybody felt:

- that there would be at least enough support for the formation of an association,
- that we could go ahead with it,
- that we wouldn't just be drumming up another institution that wouldn't be useful
- that it would provide a focus for industry support
- that it would be a focus for educating the public and for generating funds in the wind energy industry.

We started meeting, as Malcolm said, about eight or nine months ago, as the members of the Steering Committee. It was not an exclusive sort of group, anybody could sit in on it and drop in on it.

There were, I think, about a hundred or more invitations that went out to people. We got a fairly good turn out at the first one and then pared that down to a group which essentially just tried to do two things:

- number one, come up with some tentative rationale for the organization,

and - number two assist in putting together this symposium.

Before I go any further I 'd like very much to thank Nicholas Teekman and DynamoGenesis Inc. without whom this event would not be occurring. I think we really should recognize that. I'd like to give Nicholas a vote of thanks as a result of all the activity that he and DynamoGenesis Inc. have undertaken.

Consequently, the Steering Committee came up with the idea of a Canadian association. We've phrased a very tentative set of objectives and mission. We've phrased a tentative fee schedule and things of that nature.

Basically, this meeting is not to discuss the mission or the objectives or the fee structure, although I'll be presenting them to you. I think that there won't be enough time to do that sort of thing. We could stay here all night trying to come to a common understanding of what the purpose of the organization should be.

I think really what we want to do is present that to you, have you think about it and then we'll be voting for a directorship for the association right near the end of the meeting.

Once that directorship has been established, I think that's when you can get your input. If you feel that we've missed any of the prime motives or objectives of the organization, or if you'd just like to input, you know, some of your own flavour to the thing, talk to the directors.

The purpose of the meeting right now, is to make you familiar with the intent of the organization and to try to set a directorship in place.

One of the fortunate things that we have going for us in this meeting is the guest speaker, whom I am just about to introduce. I have heard from other sources that he is an individual who has done an awful lot of good for the American Wind Energy Association.

He was educated, a Bachelor's Degree, at Haverford College in Pennsylvannia. He has received a Law Degree from the Catholic University in Washington, D.C. He's been the Executive Director of the American Wind Energy Association since January 1981. Before that, he was a legislative assistant functioning in the renewable energy area for Congressman James Blanchard.

I'm really glad that we have Tom with us today. Without further ado, I'd like to introduce Tom Gray.

CHARTER MEETING

"BENEFITS OF A WIND ENERGY ASSOCIATION"

Thomas O. Gray, guest speaker
Executive Director, American Wind Energy Association

Introduction

Given the title of my speech, it seems fairly obvious what my purpose is for being on the agenda here today.

Nevertheless, I'm glad the conference organizers asked me, and I believe I have some worthwhile thoughts to contribute as you consider initiating a Canadian Wind Energy Association.

Some of the benefits of a wind energy association which I am about to enumerate to you will also be obvious. Some others are not quite so immediately apparent -- in fact, I think in some cases, I may be the only person in AWEA who sees them. So it's probably a good thing that I was asked to speak to you.

About AWEA

First, though, let me tell you something about the American Wind Energy Association, where it came from, and what it is today.

AWEA is the trade association of the American wind energy industry, representing primarily manufacturers of wind energy equipment and related components.

Its membership breaks down into three categories:

We have about 125 corporate members -- companies of all sizes who find our activities to be in their interest to support. At one end of the scale, we have the Boeing Company, and at the other, dozens of small, one-room operations building prototype wind machines or selling them or consulting. Dues for our corporate members range from $250 a year to a peak of $5,000, based on number of employees, and about three-fourths of them fall in the lowest dues category.

Let me mention also that some very large companies are members of AWEA at modest rates. For example, Exxon is a $250 member, and Dresser Industries pays us $500. This is because of a problem which every specialized association faces -- how to handle a large corporation which has only a small interest in the field represented by the association. We have dealt with the problem by explaining to each company that we will accept a dues payment based upon the number of employees that the company has working on wind energy. Exxon has one employee who simply monitors the industry, so they fall in the lowest dues category.

I like this approach because it is both generous and practical -- the two qualities I try to aim for in conducting AWEA's business. We could tell Exxon to pay us the maximum of $5,000 or forget it, and it's almost certain they would forget it. That would benefit no one. We would get no money, and they would get the information they are seeking about the industry from someone else.

Services provided to our corporate members consist primarily of our weekly newsletter and a variety of special mailings on matters of interest. Also, corporate members are kept fully up to date on actions taken by AWEA committees and have a full opportunity to participate in the Association's activities.

Next, we have about 100 associate members. Some of these are individuals in government agencies who support the goals of AWEA and are interested in receiving its weekly newsletter. Others are small companies who cannot afford even the lowest category of corporate membership. And some are companies trying to get by on the cheap.

And finally, we have about 400 individual members. These are a wide variety of people, some of whom are simply private citizens who support wind energy for ideological reasons. Most of the rest are wind systems dealers or academics.

Both the associate and individual members are treated simply as newsletter subscribers. Associates receive Wind Energy Weekly, and individuals receive the Windletter, which is published eight times a year.

We also have a subscription option for Wind Energy Weekly. An associate membership costs $125, and with it, you receive the Weekly. However, if you prefer, you can subscribe to the Weekly for $125 a year. Again, this option is rooted in practicality. When we send membership information to people, particularly those overseas, we find that many don't look through it carefully enough to find out that an associate membership entitled them to a weekly newsletter. For those people, a newsletter solicitation presented in traditional terms brings a better response. Currently, we have about 60 subscribers.

Again, let me emphasize that there is always a problem with structure, in that some companies or individuals will want to get by as cheaply as possible.

There are two basic ways to approach this: one is to refuse to allow such a company or person to join, and the other is to allow them to become members and then work on them. We have chosen the latter approach, for several reasons. My feeling is that it's very difficult to be sure that a company is joining in the right category, and that a committee of some sort would have to go over the applications and waste a lot of time and energy. Also, we have found it fairly easy to persuade associate members to upgrade to corporate membership, using a discount for first-year corporate dues.

So that is what AWEA looks like today, with a little of our philosophy on associations thrown in. It is possible, of course, to take a very different approach. The National Hydropower Association, for example, with which I am also quite familiar, has a miniumum dues level of $400. They do not worry about companies who cannot afford $400, but feel that those companies should join regional or state associations instead. Their philosophy is that they prefer to deal with the larger firms.

On to the benefits of an association. I have attempted to prioritize these without success, so I am going to simply enumerate them.

Protection

The first benefit is protection. In the U.S., and I think elsewhere in the world, government is playing a role which is increasingly important to business. And the wind energy industry, which is attempting to develop an energy source that is quite marginal economically, is more dependent than most on government support.

As I am sure you all know, the wind industry in the U.S. would not exist in anything like its present form today without three major pieces of government legislation: the Solar Energy Research, Development and Demonstration Act, which founded the federal wind energy research program; the federal energy tax credits, which have provided financing for the windfarms; and the Public Utility Regulatory Policies Act (PURPA), which has provided a guaranteed market for wind electricity. A threat to any of these, and even to some more minor legislative items, can be a serious problem for the industry.

Looking back over the past three years, I can think of at least three times when AWEA has learned of potentially damaging proposals and helped to head them off by letting our members know or by working with other groups in Washington.

Two years ago, the Treasury Department proposed to abolish the energy tax credits.

Also two years ago, the Federal Energy Regulatory Commission proposed a fee schedule under which the owner of a residential wind system might have had to pay over $50,000 to the Commission to have it certify that his machine qualified under PURPA.

And last year, the Treasury Department proposed to change the tax depreciation period for wind systems from five to 15 years.

None of these proposals ever went beyond the discussion stage, thanks in part to AWEA.

When the issue of abolishing the credits came up, we and other renewable energy groups, with the help of our members, were able to persuade majorities of both houses of Congress to cosponsor resolutions opposing the idea.

We fought the fee schedule by having our membership mail prepared letters to the Federal Energy Regulatory Commission opposing it.

And by explaining the effect of the depreciation idea to key Treasury staff, we were able to prevent it from ever even being formally proposed. That, by the way, is the ideal solution, because no matter how little chance something may have of becoming law, once it's been proposed, it has a negative impact on the financial community.

So protection is one of our functions. An individual company could obtain the same protection by hiring its own lobbyist or law firm in Washington, but that would be much more expensive than even a $5,000 membership in AWEA.

Unity

The next benefit AWEA provides to its members is unity. Even in an established industry, there are probably as many situations in which companies should cooperate with each other as compete, and that is much more the case in a very new industry like ours.

One reason for cooperation is that it's much harder to get government to give out benefits than to take them away, and to get it to take away regulations than to impose them.

It's very tempting for some of our members to criticize the federal wind energy program, for example, for putting too much emphasis on large wind machine development.

In so doing, however, they overlook a number of things:

1) A large machine provides a publicity focus, making it easier for the program to obtain money in competition with other federal programs.

2) Money taken away from large machines will not be redirected to other wind systems. It is much more likely, in this time of budget deficits, to be taken away from wind energy altogether.

3) The real competition for small wind systems is not large wind systems, but coal and nuclear energy. They are the ones with the U.S. Committee for Energy Awareness, running television commercials and full-page newspaper ads that belittle renewable energy.

Our job, as an association, is to point out the benefits of cooperative action and the liabilities of unhealthy competition.

By cooperating, the industry may be able to succeed in encouraging the development of a balanced, worthwhile federal research program. Without cooperation, that's almost impossible -- and yet, ours is almost the only voice raised in the industry on behalf of a cooperative approach to these problems.

Information

A third benefit AWEA provides to the wind industry is information. Our high level of activity in this area reflects my own personal background as a daily newspaper reporter, but even if we were no more active than other associations, it would still be a major function. Why?

- Legislators and regulators need information about the industry to make intelligent policy choices.

- Private citizens need information about wind energy to determine whether it is right for them.

- Small wind energy companies need information about government programs and regulations to do business.

It's very difficult to get information about the wind energy tax credits and proposed legislation affecting them, for instance, if you live in Oklahoma City. The local newspapers carry very little in-depth news on national legislation, and even the New York Times and Washington Post gloss over minor items. This year, when a proposed extension of the credits was blocked, the Post never mentioned the fact, referring only to "energy conservation credits."

AWEA fills the gap for small companies located around the country, and meets others' needs for information about the industry as well.

Representation

A similar, but slightly different, benefit that AWEA provides is representation.

I am the only person in Washington, DC, outside of the federal government whose full-time job is to look after the interests of the wind energy industry.

Our small members have no government relations staff in Washington. The few large members have lobbyists, but like their companies, they are concerned about many issues, and wind energy is a low priority among those issues.

Also, any individual company is presumed, by Congressional members and staff, to be representing only its own special interests, rather than those of the industry as a whole.

AWEA therefore plays a crucial role as a spokesman for the industry, not only in government policy circles, but with the press. In a typical week, I will do two or three interviews with media of all sizes and types, ranging from local weekly newspapers to the national television networks. And my message is always the same, always supportive of the industry as a whole, never slanted toward horizontal-axis machines as opposed to Darrieus, or large as opposed to small, or any one company's interests as opposed to all the others. I think that's a valuable service.

Identity

AWEA's work in representing, unifying and informing the industry results in a less tangible, but real benefit -- identity.

Our annual conference provides a forum where industry members can come together and exchange views. Our newsletters tell about activities which we are pursuing on behalf of the industry as a whole.

So when your company is a member of AWEA, you are part of the wind energy industry, not just an individual out in Omaha or Salt Lake City or someplace trying to make a buck. And you learn to be concerned about what happens to a wind systems owner somewhere else, because it affects you. That's an important part of the maturing of an industry, and it follows naturally from an association.

Commercial Opportunity

AWEA also provides its members with commercial opportunities.

Our conference allows corporate and associate members to exhibit their equipment at rates which are well below normal commercial trade show levels, and our newsletter lets members know about chances to bid on government contracts, about contacts we receive from distributors in other countries, and other opportunities to do business.

Political Sophistication

And finally, AWEA provides companies, most of whom have little or no experience in politics, with political sophistication.

My own experience in politics, at the local, state and national level, spans almost 20 years, and it's a valuable asset to many of our members.

Again, let me give you a concrete example.

The energy tax credits for both business and residential wind systems expire at the end of next year in the U.S.

This year, the business credit will probably cost the federal government about $75-$90 million, while the residential credit will cost less than $5 million.

Given the large federal deficit, it naturally seems that winning an extension of the business credit will be more difficult. But that is not in fact the case.

Why? Because the residential wind credit is coupled in most legislators' minds with the residential solar and residential conservation credits, both of which are much more expensive and not terribly well thought of. Both will cost hundreds of millions of dollars this year.

What can we do on the residential side? Well, the best strategy is to concentrate on one member of the House Ways and Means Committee, and try to persuade him to ask the chairman to extend the credit, pointing out its low cost. Not only is it the best strategy, it is the only strategy which stands a chance.

Whether we will win on this issue or not, I don't know. But I do know that without AWEA, there wouldn't be a chance, because our residential systems companies would not have a clear idea of how to approach the problem.

I could give many other similar examples but time does not permit, and I am anxious to hear and respond to any questions you may have.

Let me conclude by again strongly urging you to form a national wind energy organization. Properly managed, such an association can provide benefits to your industry far beyond its cost, and I believe the decision to organize it is one you will not regret.

CHARTER MEETING

ELECTION OF DIRECTORS

Chairman:

Thanks very much. I really appreciate the perspective that you've been able to draw on the whole area. As neophytes getting into it just for the first time, we want to know the types of things that you've been able to promote and the successes that you've had. We also need to know some of the failures that you've had so that perhaps we can avoid some of them.

In that regard, Tom told me story a little bit earlier, that I want to share with you. Early on in the development of the American Wind Energy Association, there was evidently a little bit of shennanigans going on. One of the early treasurers of the Association absconded with some of the early support to the industry and ran north to Canada. Just a little perspective on the thing...

FROM AUDIENCE

Where is he now?

Chairman:

We don't know. We've been looking for him.

The next task is a presentation of the MISSION AND OBJECTIVES of the Association. I want to state these in simple terms, not primarily for discussion, but just to give you a feel for them. In terms of the mission: we want to: 'promote and develop wind energy technology in Canada' and also focus on the 'export market'. We'd like 'to advance the products and the services' that the wind energy industry can provide across Canada and in the export market. It is a very general statement and I think could use some refining. As soon as the Board of Directors is in place, a number of these things can occur.

The objectives.

The first objective that we have phrased here, largely is 'to coordinate and serve the interests of the wind industry, particularly in terms of technical standards', although the Canadian Standards Association is coming up with what could be called a set of standards for the wind industry. We feel that the association should have a strong say in the development of 'standards, trade information and research and development'.

The second objective that we've phrased is 'to represent the interests of the industry in the financial community'. This is something that is so frequently overlooked. I think one of the presentations that was given this morning focussed very neatly on the industrial potential. A number of them did, but the one that I recall from this morning was the Deltx experience. What they've done is target at a water pumping market. It's a very large market and I think that the financial community has been responsive to the way in which they've phrased their case. As we learn more from these types of experiences, we can share the experiences and the approaches amongst each other. In this manner, the successes can widen and the industry as a whole can be strengthened.

The third objective that we've phrased is really 'to educate and inform', that's a fairly simple one. Inform both the public and agencies as well. It's fairly evident that certain agencies are already well aware of the wind energy industry. But I think that there are a number of agencies that could be briefed in a more complete manner than they are right now. Really, by discussing in a public forum, the economic performance and industrial benefits of a strong industry in Canada.

The fourth is 'to represent the interests of the industry to the government'. There's a little bit of spillover in terms of public presentation and agency presentation. I think that both are very important focuses.

The next item on the agenda is a presentation of the proposed duties of the directors that you will be electing shortly.

The main duties of the directors will be to set an executive in place and to generate the memberships, corporate sponsorships and associate sponsorships of the Association.

A President, a Secretary and a Treasurer will be elected amongst the directors.

They will be drafting and ratifying bylaws in respect to memberships, fee schedules, patents and things of that nature that are necessary to set the association in place.

They will be developing and hopefully ratifying the objectives and mission of the Canadian Wind Energy Association.

Hopefully they will be able to pull together a newsletter.

They will be able to focus on future wind energy symposia, which was one of the prime motivations for setting the thing in place.

Hopefully, they will be able to establish a place, an office, where they can hang their moniker on the outside door, to provide services both to the public and to the industry.

They'll be able to gather information on things such as utility policies, government policies, product information, a variety of things of that nature.

It has been thought initially that it would be good to rotate within the Board of Directors. This is just a notion that people have at this point. When the board is in place, they hopefully will consider it. We hope to give the association some continuity by giving two of the five directors a two year term. Those two people will be the people who get the most votes this afternoon. The other three will have a one year term. As I said, the two year terms will be given to the Directors who have the most votes. Hopefully, this will provide continuity throughout the beginning of the association.

The proposed membership structure that you have in front of you. Again, I must say that it's just proposed. Any of you who feel strongly one way or another about it, should probably talk with the directors who will be announced at the banquet tonight.

We've suggested a $30.00 fee for an individual who let's say, is a homeowner who's interested in supporting the association but not much more. We've suggested a break for students, which I think is warranted. I believe that, hopefully, a lot of support for the Association, from a public point of view, can be generated amongst the younger portion of the population. Hopefully, a large contingent of university people will get involved.

From that point of view, I don't know whether the directors will decide that they should be associate members if they are from a university and representing the university or if they just get involved with the $10 membership for students.

We have what we call an associate membership at about a $300 level. That's fairly close to what Tom was talking about. I believe that there is enough support for that level that we will see a number of memberships at the associate level.

We are thinking about a $1000 corporate membership. Again, these are relatively flexible and, I would suggest, form guidelines for future discussion.

We will be accepting nominations from the floor for potential directors. We are going to ask for seconding of the nominations.

In addition to that the Steering Committee has, within its own context, suggested a variety of individuals who could be put up for nomination. I'll be announcing those names in a couple of minutes. I suggest that you take the next minute or two to think about whether either you personally, or somebody you know would like to be nominated. We'll be taking those nominations very shortly.

There are a variety of forms that you have in front of you and

I'd like to just briefly go through them with you.

The salmon is the nomination form. Please notice the spaces for the name of the person that is being nominated and the name of the seconder, the person that is nominating the individual. At the same time we are asking the people who have been nominated to agree that they will stand for directorship. We'd rather not have people vote for an individual who doesn't really want the job.

There is, along with the salmon form, a blue form where you are being asked to list your choices for the directorship. The second part of the form is optional. If you have any feelings concerning the Charter Meeting and the Objectives, there is a little bit of room for comment. There is also a little bit of room for comment on the proposed fee structure. These blue forms, once you've laid out who you are voting for the directors, will be collected on your way out the door. I believe that Monique, if she'd be good enough to hang in there for a little while will pick those up. Monique will be collecting those just as you leave the meeting.

I would request that the nominees stay in the vicinity of the room for a little while. Either that, or leave a place that you can be reached. This is quite important, because it's not going to take us a long time to count up the ballots. What we'd like to do before the banquet this evening is to indicate to the people who have been elected, that they have indeed been elected. We'd like them to know about it before the banquet so that we can make an announcement in the banquet. They are going to be sitting, hopefully, at the head table, this evening. You'll be able to distinguish them, at least, that way.

We are hoping that the people that are nominated can be reachable. You can leave a spot, a telephone number, a room number or hang in for the count. If you are going to leave a telephone number or room number please leave it with me at the front just before you leave.

We also have another form, which is a questionnaire. It's a questionnaire on the demand for CANWEA services. We ask you to fill out the form before you leave the meeting tonight. It won't take too long, hopefully. It will give us an idea of the types of services that you feel will be most useful for the association to embark upon in its fledgling year.

I don't think I've missed anything. What I would like to do now is to suggest that nominations for the directorship are open.

I am going to just start the process. Are you going to write them down on the overhead, Nicholas? Do you want to slide over there and take the names down as I indicate them?

This is, of course, just the Steering Committee's best shot at who we felt might be good directors. It's going to be up to you to elect or not elect them. We'll be taking further nominations from the floor. I'm going to start at the bottom of the list and work up, just to make sure it's not prejudicial in any way.

Vince Lacey has been nominated from DAF-Indal and seconded.

Albert Watts from the Institut de Recherche d'Hydro-Quebec.

Somebody had the good sense to nominate Malcolm Lodge from Resource Ventures Incorporated.

Alex Printzios has been nominated from ADECON of Toronto. I'm very happy to see that personally.

And the fifth person that the Steering Committee has come up with, in its undying wisdom, is Jason Edworthy of Nor'Wester Energy Systems from Calgary. I also feel this an excellent suggestion. And we don't want to stop there.

I think what I should do now is let you think for a minute or two and I will recognize people who raise their hands to nominate others from the floor, now.

I see an overwhelming rush here.

Going once...going twice...how are we doing on time? I don't have a watch on. Five-fifteen? We've got plenty of time. If you would prefer, right now we'll take a five minute break and come back into the room so you can consider who you'd like to nominate further. If that's a good idea, all rise. If it's not then we'll stay here and work the rest of it out. You want to take a five minute break and come back? Please try to be back in the room in five minutes.

(PAUSE FOR FIVE MINUTE BREAK)

Can the people at the back of the room see the board now, I'm told that there was a problem with it when it was over on that side. Is it legible? Everybody's happy?

Several comments were made to me in the interim. One of them was that in the objectives section there might be a little more emphasis placed on R & D as one of the objectives of the Association. I would say that is a very good suggestion, I see Marc nodding avidly, and that the directors should seriously consider it as perhaps an addition to the objectives statement.

There was another comment and I think a fair one. The individual membership at the $30 level or the student at $10, were they really a member if they weren't allowed to vote? Were they just a subscriber to a news bulletin?

I think maybe just a little bit of discussion on this topic amongst the directors, once they're elected, may be appropriate. The concern is whether it is equitable to have people involved in an association but not allowed to vote, or whether it should be based on a monetary capability. If you can come up with 300 bucks you can vote, but if you can't fork up the money you can't vote, is that fair? I think that as part of the development of the association, these things should be taken into account. There were no further comments made to me. All I wanted to do was relate to you what happened in the interim.

I will now open up the meeting again for any further nominations from the floor.

I see one at the back. A little louder please? Mary Ellen Jones from Deltx, from the Alberta corporation. Is there a seconder? All right, seconded by the gentleman at the back. We will note same. Mary Ellen Jones on the board up here and take a salmon coloured paper for it.

Basically, now that you've had enough time to consider the nominees, including now Mary Ellen Jones, I would ask you simply to fill out the blue ballot form as you are sitting here now.

Please consider the one, two, three, four, five in your own preference. I would appreciate it if you would list the five people that you feel are most appropriate. Please, list them in order of preference because the first two, number one and number two are going to be the people that have the two year tenure. Please just carefully consider that. Fill out the ballot. If you want to fill out the second section of the ballot, please do so. If you don't want to at this stage, it's not necessary.

We will write down all the affiliations of the nominees. Yes sir? I am still willing to accept any nominations if they come forward at this point. Nominations are closed. Thank you.

Given the size of the group right now, I think I'm going to request Vince, Albert, Malcolm, Jason, Alex and Mary Ellen to stay in the vicinity. Either in the room or just outside the room, as we are counting. I don't think it's going to take very long. Have you had enough time to fill out the ballots?

Is there anybody who hasn't had enough time to fill out the ballots? Jack...okay we'll wait a minute...

The only other announcement that I have is that there is a cash bar next door and it opens now. I hope you enjoy it. I'm afraid I can't stay around myself because I have got a two-month old baby to get back to, but I'm with you in spirit.

Thank you very much for attending the meeting. On the way out, Monique will take the ballots from you. The announcement of who the directors are will be made at the banquet tonight. Again thank you very much and good night.

CHARTER DIRECTORS-ELECT FOR CANWEA

Malcolm Lodge Resource Ventures Inc.	President
Vince Lacey DAF Indal Ltd.	Secretary
Alex Printzios ADECON Energy Systems Inc.	Treasurer
Albert Watts Hydro-Quebec	
Mary Ellen Jones DELTX Windpump Corporation	

BANQUET

BANQUET

Monique Carpentier, Moderator
Energy, Mines and Resources Canada

Introduction

Good evening, Ladies and Gentlemen. It's about time to start now.

Welcome, to the Wind Energy Symposium banquet. I will be your Master of Ceremonies tonight.

For those who don't know me, I'm Monique Carpentier. I am the wind engineer at Energy, Mines and Resources. I guess, taking into consideration what has happened on the federal scene during the last month, I should probably say that last Friday when I left the office, I was their wind engineer.

This symposium, when compared to the six previous ones, is a very special one. For one thing, it is the first two day event. But most of all it has led to the formation of the Canadian Wind Energy Association.

CANWEA has the potential to become the focus point for all people interested in the wind energy option. For the first time, the wind energy community will have a common voice. It is up to us to make this Association a very useful and successful one.

In recognition the importance of this event, tonight's head table is composed of our guest speaker and four of the five elected directors of CANWEA.

I will now introduce the head table. Starting with my left, with Vincent Lacey from DAF-Indal, Mary Ellen Jones from Deltx, Andy Wells, Tom Gray from the American Wind Energy Association, Malcolm Lodge from Resource Ventures Incorporated, and Albert Watts from the Institute of Research of Hydro-Quebec. The fifth elected Director was Alexander Printzios, but he cannot be here tonight.

The two people that will serve for the two year term, that being the ones who got the most votes, are Vincent Lacey and Malcolm Lodge.

I guess everybody is quite hungry now, so we will ask Vincent Lacey to say the grace.

VINCENT LACEY

May we be truly thankful for what we are about to receive, Amen.

MONIQUE CARPENTIER

Thanks Vince. Well, I hope you enjoyed your meal. I must say that it's probably one of first times that a Wind Energy Conference or banquet that I have been to is not having rubber chicken, as Malcolm would say. I really appreciated the meal, I hope you have too.

It is now the time for entertainment.

Our speaker tonight was an early promoter of renewable energy and also energy conservation. He started public life as a school teacher, a very good beginning. He then decided to move to other more relaxing jobs, so he became principal secretary and political advisor to Alex Campbell, Premier of PEI for sixteen years. He planned and directed the implementation and operation of the 1977 Canada-PEI agreement on renewable energy development. He is now the Executive Director of the Institute of Man and Resources and as well as of Resource Ventures Incorporated.

As almost everybody has, he has some faults, and it would certainly take too long to enumerate all of them, but I have only one for you tonight.

For someone living in PEI who apparently heats his house only with wood, this fault is an important one. According to what he has told me during dinner time, PEI is one of the best places for wind energy in Canada. Yet he doesn't have a wind machine on his lot!

I hope when the banquet is over tonight, that companies selling wind turbine equipment will approach him and make him feel very bad about it. I hope you will be able to close some deals. (Floor - He doesn't have any money!) Well, I am sure he will be able to find it. So please welcome Mr. Andy Wells.

SOLACE IN LITERATURE

Andy Wells, Executive Director
Institute of Man and Resources

Presentation

Well, with an introduction like that who needs friends?

Someday I'll lick it, I'm sure I will, just as those in the audience who support wind energy will someday lick the problems of financing wind energy systems. The day that happens, the day we find that wind energy systems are available at cost and meet the competition, that's the day I'll quit smoking. It's a pledge.

I must say that when Malcolm Lodge approached me a week ago Sunday to see if I would speak to this group at the banquet I confess to asking myself, "why me?" Sure. I've been around the field of renewable resources off and on since 1973 and I suppose that gives me a certain amount of credibility, but my technical competency in the field of wind is virtually nil. I frankly wouldn't know the difference between a wake and a funeral. I understand that Marc Chappell does.

(FROM THE AUDIENCE) There is no difference!

Thus the invitation to me to speak, I confess, gave me pause for thought as to the gravity, the seriousness, of this, the Seventh Annual Wind Energy Symposium. However, when I was told whom I would be replacing as your preferred guest speaker, I have to admit that you've gone from worse to bad. Given the present circumstances surrounding the development and deployment of renewable energy it is very tempting to spend the next 20 to 30 minutes lamenting the present economic and political climate. - God knows, we can do that! - I could extoll the virtues of renewable energy, in particular, given the nature of this organization and gathering, that of wind. I could lambaste the niggardly amount of money available for research and development. I can do that. God only knows, I've done it often enough over the past eight or ten years. At this time, in late 1984 it would be easy enough to do it again.

I'm sure many of us here tonight feel as did Sir Winston Churchill, when he said:

"I have a tendency, against which I should, perhaps, be on my guard, to swim against the stream."

In fact, some of us, those more righteous, might even feel like Canute, King of England, Norway and Denmark when he sat down at the edge of the sea and commanded the tides to retreat.

However, in times of depression, personally, I often turn to my first love, literature for solace and relief. Monique failed to mention that my major in studies was that of literature. In times of depression I turn to literature for solace.

So tonight, I thought I might share with you some of the insights I have gained from the wonderful world of literature.

The programme and project cuts and eliminations announced last month and those anticpated in the April budget, have been very much in the forefront of all of our minds. In fact, I have found in circulating around tonight that I can't find a discussion which doesn't include that sort of consideration. Rumours, feeding on rampant gossip have been running wild from one end of the country to the other. Officialdom in Ottawa swings wildly, much like the tail of a windmill searching for the wind: from suppressed anger, to bemused frustration, to outright confusion.

However, there is some comfort in that there is reference to renewable energy research and development, and the finance minister's economic statement to be found in the Book of Common Prayer:

"In the morning it is green, and groweth up: But in the evening it is cut down, dried-up, and withered."

And surely we find reference to Don Strange in ISAIAH:

"Surely he hath borne our griefs, and carried our sorrows, ...
(and then)....He was cut off out of the land of the living."

But we can all take comfort and insight from Rudyard Kipling when he wrote in The Young British Soldier:

"When you're wounded and left on Afganistan's plains,
An' the women come out to cut up what remains,
Jest roll to your rifle and blow out your brains
An' go to your Gawd like a soldier."

William Ellory Channing must have had Malcolm Lodge in mind when he wrote Tears in Spring:

"A wail in the wind is all I hear: a voice of woe for a lover's loss."

Lewis Carroll knew well how new governments work. In Through the Looking Glass, Carroll said:

"It isn't etiquette to cut anyone you've been introduced to.
Remove the joint."

Lord Byron could have had our Finance Minister in mind when he wrote in Don Juan:

"He was the mildest manner'd man
That ever scuttled ship or cut a throat,
With such true breeding of a gentlemen,
You never could devine his real thought."

And of course, Jack Templin and Raj Rangi would identify with Shakespeare's Julius Caesar when he said:

"This was the most unkindest cut of all."

All of us who, over the years, have struggled to keep renewable energy in the government game, will understand Roy Campbell, when he wrote:

"You praise the firm restraint with which they write - I'm with you there of course. They use the snaffle and curb all right, but where's the bloody horse?"

Rumour has it that Don Strange can be found wandering around the corridors at 580 Booth Street mumbling to himself these famous lines from William Congreve's Pious Selinda goes to Prayers,

"Wou'd I were free of this restraint,
Or else had hopes to win her;

Wou'd she cou'd make of me a saint,
Or I of her a sinner."

Nor are Don's helpers immune from the need to recite poetry. I understand at each day's end Jack Cole, Tom Ledwell, John Waller and Monique Carpentier, gather together and recite John Dryden:

"When I consider life, 'tis all a cheat:
Yet fool'd with hope, men favour the deceit:
Trust on, and think tomorrow will repay:
Tomorrow's falser than the former day:
Lies worse, and, while it says, we shall be blest
With some new joys, cuts off what we possest."

Charles Dickens knew the ins and outs of it all. As he wrote in the Pickwick Papers:

"It's over, and it can't be helped, and that's one consolation, as they always says in Turkey, ven they cuts the wrong mans head off."

We have all heard of the golden handshake. However, William Shakespeare must have had our federal government in mind when he wrote, in Romeo and Juliet:

"Though cuttest my head off with a golden axe."

Or as George Crabbe so succinctly put it in his Widow's Tale:

"... cut and came again."

Those of us involved in the renewable energy field, have made no secret of our conviction that conservation and renewable energy is the preferred energy choice.

Speaking of secrets, another item of interest that we, even in Prince Edward Island, hear emanating out of Ottawa is the new government's penchant for secrecy. I'm sure that government knows what it is doing, but just in case, reference to literature can only help.

Ecclesiastes can provide a perfect model for the new credo. That's credo, not CREO, for the Ottawa mandarins:

"Fear God, and keep his commandments:
   for this is the whole duty of man.
For God shall bring every work into judgment,
   with every secret thing,
whether it be good, or whether it be evil."

Our local poet, Honest Harry, writing in the Summerside Journal last Saturday suggested the impending problems of many Ottawa public servants,

"Yesterday, I had a spot in the public service;
Now I'm out on UIC and getting mighty nervous;
There's not much work on civvy street,
Just as I suspected;
To land a job with no known skills,
You have to get elected."

And the Ottawa public servants can think of Robert Surtees' line found in Mr. Facey Ramford's Hounds when they contemplate their political masters:

"There is no secret so close as that between a rider and his horse."

However, the general public may not view government secrets as being so sacrosanct as do those keeping them. George Meredith perhaps put it best in Modern Love when he said:

"They have the secret of the bull and lamb.
'Tis true that when we trace its source, 'tis beer."

I sometimes think Charles Dickens must have known Erik Neilson. Who else could he have been thinking of when he penned these lines in A Christmas Carol?:

"Secret and self-contained, and solitary as an oyster."

I certainly hope our Prime Minister doesn't read William Shakespeare, otherwise he may take these lines from King Henry the IV to heart:

"Constant you are,
But yet a woman: And for secrecy,
No lady closer; for I will believe
Thou wilt not utter what thou dost not know."

But the best advice of all that the Prime Minister can get from literature comes from the mouth of Benjamin Franklin:

"Three may keep a secret, if two of them are dead."

On this subject, a final word of advice for our senior public servants in the audience can be found in Samuel Taylor Coleridge's The Ancient Mariner. Any resemblence to Erik Nielsen or Robert De Cotret is quite coincidental:

"Like one, that on a lonesome road
Doth walk in fear and dread,
And having once turned round walks on,
And turns no more his head;
Because he knows, a frightful fiend
Doth close behind him tread."

How then have these recent government announcements and budget cuts really affected renewable energy development and some of those people most directly involved. Let us again turn to literature.

Coleridge might well have been writing in The Ancient Mariner, about the meeting of the renewable energy ship of state with that of government policy:

"Under the water it rumbled on,
Still louder and more dread:
It reached the ship, it split the bay:
The ship went down like lead."

I am reliably informed that the response of Marc Chappell can also be found in The Ancient Mariner:

"He went like one that hath been stunned.
And is of sense forlorn:
A sadder and a wiser man,
He rose the morrow morn."

Edward John Moreton best summed up the common reaction of many governments to the concept of renewable energy:

"A new thing came and they could not see, and the wind blew and they would not feel it."

Ecclesiastes offers words of caution to those of us, however intemperate, who would promote renewable energy to governments:

"He that observeth the wind shall not sow; and he that regardeth the clouds shall not reap."

But no wind aficionado can help but turn to Miguel De Cervantes. For those engineers and science types, I should point out that Cervantes authored Don Quixote. For those really benighted individuals, I would further point out that Don Quixote, the knight in shining armour, is best remembered for tilting at windmills. I like to think of Marc Chappell when I read this description from Cervantes, "The Knight of sorrowful countenance" and of energy consultants with these lines:

"The best sauce in the world is hunger."

This line from Don Quixote suggests the fate of wind machine manufacturers:

"Where there's no more bread, boon companions melt away."

But there is also hope to be found in Cervantes. What better description of our hopes and aspirations for the rebirth of renewable energy can we find then:

"Fortune may yet have a better success in reserve for you, and they who lose today may win tomorrow."

Or: "Every dog has his day,"

And finally: "Even a worm when trod upon, will turn again."

But Cervantes does suggest there may be dark days ahead. We have the April budget, after all, to look forward to. He says:

"Ill luck you know, seldom comes alone," and, "you may go whistle for the rest."

Thomas Dunn English could have been writing about Nicholas Teekman when he said:

"Less good from genius we may find
Than that from perserverance flowing;
So have good grist at hand to grind,
And keep the mill a-going."

Henry Austen also spoke of Nicholas:

"Genius, that power which dazzles mortal eyes, is oft but perserverence in disguise."

I've heard from sources inside the National Research Council, which despite the recent policy directive, wish to remain anonymous, that Phil Cockshutt has disappeared behind his office door and can only be faintly heard quoting the verse of Alfred Lord Tennyson:

"I am going a long way
With those thou seest - if indeed I go -
(For all my mind is clouded with a doubt)
To the island-valley of Avilion,
Where falls not hail, or rain, or any snow,
Nor ever wind blows loudly; but it lies
Deep-meadow'd, happy, fair with orchard lawns
And bowery hollows crown'd with summer sea,
Where I will heal me of my grievous wound."

In fact, these lines of Matthew Arnold from The Forsaken Merman could bring solace to us all:

"But, oh, she gave me never a look,
Her eyes were seal'd to the holy book.
Loud prays the priest; shut stands the door.
Come away, children, call no more.
Come away, come down, call no more.
She will start from her slumber
When gusts shake the door;
She will hear the winds howling,
Will hear the waves roar.
We shall see, while above us

The waves roar and whirl,
A ceiling of amber,
A pavement of pearl.
Singing, 'here came a mortal,
But faithless was she!
And alone dwell for ever
The Kings of the Sea."

In thinking about literature, my mind turns to these lines:

"Little deeds of kindness, little words of love,
Help to make earth happy, like the heaven above."

The author of that pleasant refrain is Julia Carney. One can only hope that her namesake will build such sentiment in her portfolio.

In closing, I should let you in on my own position as it's reflected in literature. William Wordsworth, in one of his sonnets, perhaps best reflects my present mood:

"The world is too much with us; late and soon,
Getting and spending, we lay waste our powers:
Little we see in Nature that is ours;
We have given our hearts away, a sordid boon!
This Sea that bares her bosom to the moon;
The winds that will be howling at all hours,
And are up-gathered now like sleeping flowers:
For this, for everything, we are out of tune;
It moves us not: Great God! I'd rather be
A pagan, suckled in a creed outworn,
So might I, standing on this pleasant lea,
Have glimpses that would make me less forlorn:
Have sight of Proteus rising from the sea,
Or hear old Triton blow his wreathed horn."

Or, as others might see me, as through the eyes of Miguel Cervantes:

"He's a muddled fool, full of lucid intervals."

Thank you.

MONIQUE CARPENTIER

I would like now to invite Marc Chappell to thank our guest speaker for tonight.

MARC CHAPPELL

Merci, Madame La Presidente.

Members of the Head Table, Ladies, Gentlemen, Reverend Lacey. It gives me great pleasure to reflect on some of the things that

Andy Wells has said to us tonight, but I must admit that I am shocked. I am shocked, not at what he said nor at the wit with which he said it. I am shocked to find somebody that has been so close to renewable energy, turns out to be literate.

Andy, like yourself, I too was moved to seek among the greater writers of our time and times before us, appropriate comments to the things that have happened. Though I respect your choice of authors, I must claim precedent for my first quote, being that of none other than the Lord himself. My initial impression was:

"Father, forgive them; for they know not what they do."

I suspect however, that the 'powers that be' might have been able to reply in kind and would perhaps have chosen a very appropriate quote, namely that from Gone with the Wind with:

"Frankly my dear, I don't give a damn."

Nevertheless, I would not feel that it would be appropriate, after the years of knowing Andy, to leave this podium without at least some kind of insult. And therefore, in the spirit with which you gave us your talk, I offer you this comment on your presentation, courtesy of William Shakespeare:

"....it is a tale told by an idiot, full of sound and fury, and signifying nothing".

Seriously, on behalf of everybody here we enjoyed and taken to heart some of the words that you have said, and in particular the spirit in which you have said them. I would like, on behalf of all of us here, to offer you two things: a very small token of our appreciation and an appropriate bit of reading which is entitled Millicent and the Wind. The latter of which I am going to pass among the audience who will suitably autograph it for your lasting memory.

Thank you very much.

MONIQUE CARPENTIER

Thank you to both of you, too. It's now time to close the banquet. I hope everybody enjoyed the meals and also the entertainment part of it. I hope that we will see all of you tomorrow morning at nine o'clock for the next session. And good night.

MALCOLM LODGE

This is a very small gathering. I hope it is not indicative of the hope in the future that we all feel for this industry and for renewable energy in this country.

I believe that we owe a very deep gratitude and honour to

Nicholas Teekman who was one small element in Andy's speech. This for the effort and enthusiasm that Nicholas has put out in the last six years, and this the seventh year, to put this symposium in place. I was a member at two or three of the early ones that were held out in Orangeville and in the country. I'm extremely grateful to Nicholas and his organization for putting this act together.

Last year we had 140 people, this year we have 40. Next year I hope we have 200. I'm not at all dismayed by the matters of the last few weeks and the last few months. I am sure that most of you here, who put the investment into this industry, will join with me in offering Nicholas Teekman and DynamoGenesis Inc. a very great hand for the effort, enthusiasm and risk that they have taken in putting this organization together. Please join with me in thanking Nicholas.

COMMERCIAL PRESENTATIONS

MARKETING THE WINDSTREAM

Debra Hrynkiw, Thermax Corporation Energy Systems Limited

Good morning.

I'd like to say that the first commandment of marketing is:

"KNOW THY CUSTOMER LIKE THYSELF."

I'd also like to start off by saying that a lot of the equations and formulas that we heard yesterday are also the same tools that are used in marketing. Scientific research and a great deal of mathematics are the tools that we use in marketing our product, as well as in the engineering of it.

A good marketing plan is, in essence, our only insurance on which we have to base our accurate marketing decisions. The science of marketing allows us to provide a wind generator of the size and output required by our particular customer profile. We have kept within the customers' guidelines through these studies. Not only is the research important, it is vital in order that we don't go beyond our customers' requirements or guidelines or expectations. We could not sell a Windstream if it had more features, more output or even better quality or design than our average customer wants or even needs.

To find out the market potential for the Windstream when it was still on the drawing board, two studies had to be done. These are called demographics and psychographics.

DEMOGRAPHICS are measureable population characteristics, typically available through a census bureau. The information gathered includes:

- sex,
- occupation,
- education,

sometimes by - geographical areas,
including whether - they own or rent their own home
and also - the average income.

The study of PSYCHOGRAPHICS gives us the acting factors of marketing, for the potential for our product. This includes:

- lifestyles,
- buying habits, how do they buy,

whether they are - cottagers,
- do-it-yourselfers,
or - outdoor people.

Through the conclusion of this analysis we were told that there was a potential market for a product with the characteristics of the Windstream: a relatively small but as yet untapped market.

With our customer profile down pat, we were able to manufacture the Windstream according to the specifications and requirements of our targeted customers.

By the way, the profile of our customer is that:

- he is average 45 years of age,
- above average income,
- he is a home and/or cottage and/or boat owner

and - he's also a hobbyist.

Thermax chose to go the direct marketing route. It was obvious we would not reach the vast majority of our customers through full page newspaper advertisements. We possibly would have reached a very small minority of them but in the end we feel we would have taken a very large loss in advertising costs.

Specialized advertising, through magazines, was a good alternative. Even the magazines we chose were thoroughly studied to ensure we were not reaching a consumer who would have little interest in our product. Analyzing magazines by studying the demographics provided by the magazines narrowed down our lists to excellent media with which we knew we could succeed.

The demographics that a magazine provides are:

- the average reader's age,
- their income

and also - the average life of each issue of the magazine.

The latter includes the second readership ability, meaning the pass-along ability of the magazine, whereby they would pass along to their neighbours or friends who they knew would be interested, thereby doubling our potential customers.

Many magazines were considered not to be right for the Windstream.

One of them studied was Palm Springs Life. This was an excellent glossy magazine, however the demographics were just not right for the Windstream.

Examples of the right magazines chosen were:

- Harrowsmith,
- Popular Science,
- Outdoor Canada,
- Ontario Out-of-Doors.

The demographics on these were just right. Also the other ad content in the magazines was in partnership with the type of ads we wanted to place.

I'd like to give you a little bit of history of some of the ads that we placed. Through this magazine analysis, we correctly chose Popular Science magazine for an ad during 1979, 80 and 81 for a 25 watt generator. This was during the energy crisis. Through this correct marketing decision we found ourself in the midst of the TC-25G phenomenon. We had offered this generator with free plans to build your own wind generator, water wheel or pedal power station. Hundreds of these generators were being purchased and it soon became evident that to best service our customers in the United States we'd have to open up a US subsidiary.

By the time we completed the establishment of a US office, added the address to our ads and a toll-free number, thousands of the generators had been sold. We proceeded to take out additional ads in Popular Science and through the years have still sold these generators through our brochures. This proved that we were reaching the right reader at the right economic time.

Thermax's popularity started to grow and requests from generator customers started to pour in:

> They wanted to monitor their system.
> They wanted to ask about voltage regulation.
> They wanted to be able to switch their systems from DC to AC.

Because of the very uniqueness of their homebuilt systems, Thermax got busy designing voltage regulators and power monitors which were suited ideally to the 25G generator. So here we could provide a complete line of accessories according to the customer's specific requirements.

By this time, our mailing list, which now numbers 30,000, was getting too cumbersome for us to effectively access the information required to make accurate marketing decisions. A mere filing system, was just not working. We acquired an IBM System 32 so that we could resell new products coming out to this same group of people.

We have the computer programed by our specifications to meet the needs of a marketing firm.

I will give you an idea of the vast amount and different methods of information that we need to access. We have 35 different programs by which we can:

- enter new enquiries,
- enter events such as:
    - shipping dates
    - invoice numbers
    - even repairs, whether they were under warranty,

and - replacement goods.

These are all customer events. We would eventually want to pull those names and addresses for future mailings.

Another sampling of the type of data required for a mailing package aimed at a particular type of customer might be a listing of customers in certain geographical areas who have purchased products within a specified time frame. Also enquiries from those same areas within a certain time frame where customers have even enquired about the availability of dealerships.

Now, that I've mentioned dealerships, I'd like to make a point.

We generally receive, on both sides of the border, two enquiries a week about becoming dealers for the Windstream. Each and every one of these enquiries is responded to. Generally one of them is a foreign enquiry which states the absolute necessity of a small system like the Windstream in their countries. They are generally impressed with the simplicity and virtual maintenance-free aspects of the Windstream. We want to know from enquiries such as these:

- what type of business that they currently have,
- would the Windstream fit in with their product line?

Or - are they someone who owns a cottage on an island with twenty other families?

So all these things are taken into consideration before we generally grant a dealership. Specialized mailing packages are sent to these dealer enquiries emphasizing the aspects which we feel would most benefit their particular applications.

We do now have a dealer network throughout Canada and the United States with particular emphasis on the coastal areas. Unlike a consumer product such as toothpaste, which virtually sells itself, our customers for a product like the Windstream are virtually the needles in the haystack. It's a relatively small market and to find these customers we have to move a lot of hay. This means that there's a lot of education required for our dealers as well. We give them a lot of advice and send them some samples of our advertising. We also suggest that they do some local advertising in their own newspapers with an invitation to come and visit a demonstration unit.

On the international front, it was actually our initial ad in Popular Science which started to bring in enquiries from foreign countries. We continued with our advertising in Popular Science throughout the years. Our originally accurate marketing decision resulted in enquiries from 53 countries. There are currently over 45 countries operating Windstreams.

There is obviously a very good potential for export marketing of the Windstream. This has now opened up new studies for us, these being country studies. For our target areas we must learn:

- their customs,
- their climates,
- their methods of agriculture.

We have to be able to present the Windstream to these foreign countries in a manner most appreciable to them. This means that it would not be wise of us to offer the Windstream as summer homepower to a government of peoples who live in grass shacks. We have to apply each country's problem to the Windstream and outline its benefits to that particular country.

Finally, through our initial export marketing efforts we now have a licence agreement in Iceland.

We have recently completed an order in our United States office with the China Industrial Development Corporation for twenty of these units for Mongolia with the assurance of imminent orders of 100 more units.

Additionally, we have sold over 100 TC25G generators to a firm in New Zealand who manufacture a wind generator of their own design. By the way, I might mention that this wind generator that's designed in New Zealand has props made out of carved plastic sewer pipe! This is kind of an interesting method of prop manufacturing.

I'd like to mention that we also attend exhibitions which emphasize:

- outdoor power equipment,
- cottagers,
- lifestyle shows, that type of thing.

We generally don't expect to come away with a lot of sales from an exhibition. An exhibition is just what it says, it's an exhibit of products. We generally think that the public goes there to see what the new products are for outdoor power equipment, wood stoves and this type of thing.

We attend these exhibitions for credibility purposes to let the public know that we are manufacturing wind generators. Over the years we have found that the scepticism about wind generating systems is becoming less and less, while the general public is getting more interested.

We, at Thermax, feel that we can educate the general public with a unit which is within their price range. They can choose to tinker with it. They can take it to their cottage or use it for hands-on personal use for those who may be considering larger units in the future.

Also, we rely heavily on press releases. Any new accessory, new development or contracts that we fulfill, we send off a press release to every magazine in which we've ever placed an ad. This keeps us in the public eye and lets the public know that wind power is a 'happening'.

In addition, I'd like to say that Thermax, although manufacturing a very tiny unit in comparison to the ones we've been hearing about at this seminar, is very proud to be a part of the industry. We feel like a child training on a tricycle for their eventual two-wheeler. We are preparing and educating the public sufficiently that they will consider larger systems in the future. This means continuing to keep wind power in their minds through our ads, our press releases and showing ourselves at exhibitions and trade shows. We are confident that we play a vital part in paving the road to partial and/or total energy independence for consumers and also towards the overall benefit of the wind association.

Our current plans include further expansion of advertising, further educating ourselves in the exporting field through government sponsored seminars. We're looking towards school programmes aimed at advertising at the industrial arts level. As a matter of fact, our first design of a wind generator - the Helius rotor kit, which came in a kit form - proved very popular with schools teaching renewable energy at a safe level of electricity, and even the fundamentals of electricity itself.

After a comprehensive study through:

- research of the existing market,
- questionnaires to current customers at random selection,
- telephone surveys, including our dealers,

we are about to embark on the development of a wind generator similar in design to the Windstream but in the range of one kilowatt. We expect availablility of the unit in the spring. Market research and study tells us that this will be our most successful venture yet. The majority of current Windstream owners have asked to be advised when these units will be ready for purchasing.

At this point, I'd like to conclude by saying that I'm confident that you will be hearing more about Thermax in the future and best wishes to the Canadian Wind Energy Association.

Thank you.

Q. I don't know much about Thermax. I'm interested in hearing a quick summary of the corporation. Are you part of a larger corporation? If not, what's sort of assets and sales have you had over the past few years?

A. Thermax started in research and development of wind generator systems approximately 11 years ago. It's first design, as I mentioned, was the Helius rotor kit.

The parent company is Thermax Corporation Energy Systems, and its subsidiary is Thermax Corporation, based in Burlington, Vermont, in the United States.

I don't have any sales figures with me, but I can tell you that sales of Windstreams, which has only been available for about the last two and a half years is closing in in the range of 1000 units.

Q. Can you give any details on the new unit? When will it be coming out?

A. It's still at the drawing board stage. We have recently acquired an engineer to work with the firm and to develop the unit. As I said, we expect availabilty of the unit in the spring when field testing will begin.

Q. In your market survey of the users, did you determine how many of the users looked at the cost assessment before they purchased their unit?

A. The majority of the people who are purchasing Windstreams are using it for tinkering purposes, or as an educational tool. I don't think they're really looking at the end profit results.

I might mention also that a lot of a customers do come to us looking for units to run their homes. We suggest that they start off with a small unit, namely our Windstream, to get their education before they jump ahead and spend thousands of dollars on a unit and then discover that perhaps the wind regimes in their area aren't correct. In fact some of these people are using the Windstream as an anemometer, which at the same time produces useful power.

A lot of our customers live in cabins that have no power whatsoever and they're still relying on kerosene lighting. This quite surprised me to find out how many actual hermits there still are in the country. Some of our customers also include hunters who have fishing and hunting cabins. Now they are bringing up their CB radios and saying, "Thank goodness, I finally have some emergency communication".

A lot of them, I don't think are looking at 'when is this going to pay for itself'? They are looking at it as an immediate educational, hands-on experience for when they're prepared for a larger unit of the size that you gentlemen are manufacturing.

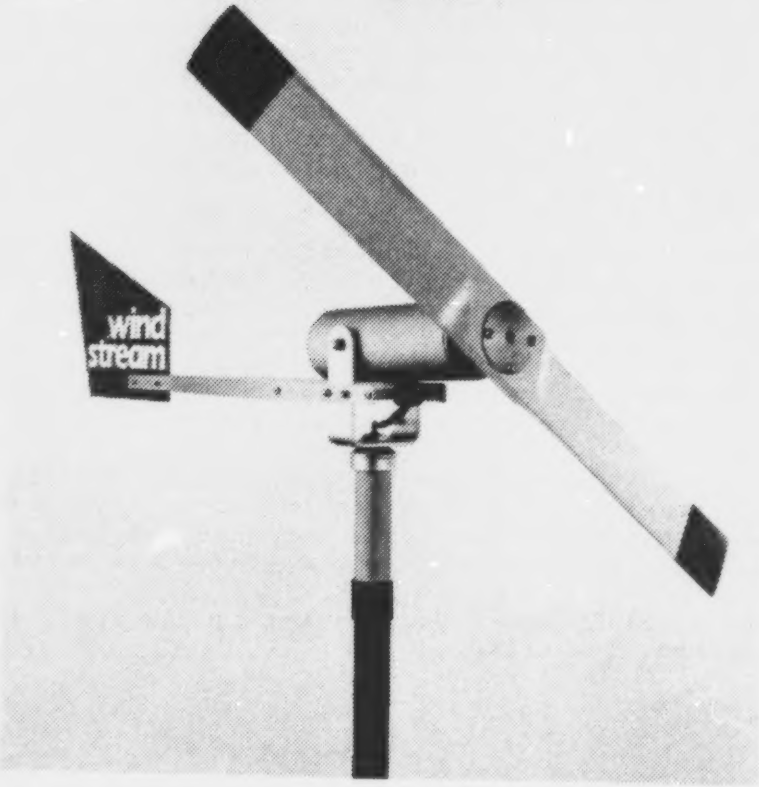
Q. So that's really where your market is you feel, in remote areas compared with urban...

A. Generally, yes. But, we are also trying to stress education of the general public whether they want to use it for a yard light or if they have a workshop in their backyard with 12 volt power tools. There has to be a real interest in wind power to be able to use our size machine as an educational tool. If a customer comes to us and has the absolute necessity for a larger system to run large appliances, then we give them your names. But we also suggest that if they're not familiar with wind power at all to start out with a small unit such as the Windstream.

Q. Just following up on what you just said, can you give us just an idea on the price per watt?

A. (Hrynkiw) Price per watt? It just so happens, our technical engineer, Mr. Kerr is here. He probably would be able to answer the price per watt.

A. (Kerr) It's something that you can't scale down that far. Well, this machine costs $400 and the maximum wattage is 200, so you can say $2 a watt, but that figure isn't really meaningful.



THIRD WORLD MARKETING

D. jeffrey Passmore, Passmore Associates International

THERE ARE THREE CRITICAL ITEMS which I want to address today, or leave with you in terms of third world marketing. Before you consider getting into marketing in developing countries you should consider these three things:

- long lead times,
- multiple visits,

and - financial risk.

All these are linked together. Obviously, the fact is that negotiations need to take place over, let's say, an average of two years. You may have to visit your prospective market, as a rule of thumb, seven times prior to consummating a business arrangement satisfactory to both parties. This results in the expenditure of larger amounts of money.

Note that I say 'satisfactory to both parties'. Two years of effort and expense guarantees nothing. You could spend all that time educating a developing country government to the point where they conclude they are not interested in wind at the moment.

Don't make a sale for the sake of making a sale.

In developing countries, of course, we don't make sales. We transfer technology; we enter into licencing agreements; or we constitute joint ventures. Seldom is a developing country government or a private company in any position to outright purchase product. They do, however, want to purchase the know-how and the means to build your product. You can stretch this process out over a three to five year period, but eventually you are going to have to give up your technology. This is a normal and natural process. There are a lot of other markets out there after you have made your technology transfer in the first one.

All kinds of different deals can be struck.

Whatever your preference, make sure there is a substantial portion of payment 'up front'. You have to protect yourself. You've got to be a tough, though reasonable, negotiator. In many cases we have offered technology where the buyer has found our price too high. That's fine, you—just don't sell it. There's no point in selling at margins which are too slim.

What I'm getting at when I say: 'don't make a sale for its own sake', is: make certain the application is good and that you have built enough overhead into the project to ensure a profit. Again, there is no point in doing projects if you are not making money on them.

I will give you an example from our own firm of a project where we lost money. We bid on the project on the assumption that the only way we were going to get it was if we bid low. We assumed that we were going to be able to do the project as part of another project. This project was in India. We were simultaneously working on another project in Pakistan. We thought: 'well, that's great, we'll just forget about the extra air fares and so on because we'll just do the job in India at the same time that we're doing the job in Pakistan'. Well, that was in July 1983. There was a dock strike in Bombay. Our shipment got held up for six months. The job in Pakistan was completed and the Delhi hardware hadn't even gotten through customs at that point. So we had to hire a subcontractor, we got into all kinds of cost overruns and indeed we haven't seen the end of the job yet. So, protect yourself.

But also protect the buyer.

The job must be appropriate for the circumstances. It must work and work well. Not all reasons advanced in favour of renewable energy, i.e.:

- reduced dependence on imported oil,
- increased energy independence,
- foreign exchange savings,
- greater self-reliance
- and - environmental protection,

are equally applicable to all types of renewable energy in every socio-economic context. Technology transfer from the laboratory or indeed even from the North American field to the user has floundered in many cases because of a lack of this understanding.

Your best marketing tool will be your referrals from past clients. Indeed, you will even get referrals from clients to whom you did not sell because you recognized and told them that wind energy was not appropriate for their needs at this time.

Suppose the official from the Indian government is talking to an official from the Thai government and the Thai government is the government you want to approach next. The Thai official learns from the Indian government that, 'indeed, this is a reputable company'. They told me: 'even though I was interested in wind, it wasn't applicable now'. Then the Thai government official is going to trust you, because he knows that you're an honest broker.

You must recognize your limitations. If you are a small firm, I would suggest that you probably shouldn't get into third world marketing at all, unless there are extremely exceptional circumstances. You'll find you simply can't afford either the financial or human input. Once you stretch your resources abroad, you jeopardize your operations at home. Your number one priority should be your operation at home. If there is nobody at home to mind the store, then things at home are going to get pretty rough when you're off selling in Kenya.

If you are a medium sized company, international work will still stretch your resources.

Be careful not to create expectations that you cannot fulfill. The last thing you want to do is develop a reputation for lack of delivery capability.

Indeed, many sectors in the Canadian renewable energy economy already have that reputation. In developing countries, resources are limited and governments do not have the capacity to absorb more than one or two technologies. The renewable energy buffet has resulted in some very real disappointments and scepticism because initial choices have failed to live up to expectations. You may find yourself going into a given market where both, for example, photovoltaic and biomass conversion have been attempted with little or no success. As a result, there is a built-in distrust of new energy sources.

It's going to take a while. That's why I say an average of seven trips to gain trust. Once you've gained that trust, you must not violate it.

If you are not comfortable with developing country markets, as an individual or as a company, then I suggest that you hire a marketing firm that knows developing country markets. You've got to be able to land on your feet.

We have direct experience with individuals who were full of brave talk about their desire to work abroad, but when they got on site, things changed. One of our former vice presidents went overseas absolutely bubbling over with enthusiasm. He spent 20 per cent of his time there wishing he was back home again, 40 per cent of his time with a bout of bad belly, and virtually all of his time frustrated because the job was taking so long to get done. You simply can't walk down the street to the local Canadian Tire and pick up parts that aren't locally available. In addition, he couldn't stand the heat. Needless to say, that particular individual is no longer with us.

Let me put this business of time frame into some perspective.

We are just completing a $200,000 job in Prince Edward Island involving 160 solar panels with all the complicated piping and instrumentation that it entails. Essentially we were in and out, except for one hiccup, in seven weeks.

By contrast, we did a $32,000 job in Pakistan involving merely 7 flat plate collectors and one Yazaki chiller from Japan. While this job was commenced in February 1984, it's still not finished even with the help of External Affairs customs clearance and diplomatic bag! The material that got lost in the first shipment was then sent in a diplomatic bag for the second shipment but the diplomatic bag was stolen! We then had to provide all the hardware again, at our cost, and finally bill the client after we had our receipts. We essentially bought the material three times before it arrived on the site.

How do you get to know your market?

Well, there's PEMD, there's CIDA and there's the World Bank. There's all the various other development banks. I suggest you try to use these, but they definitely have their problems.

PEMD has a reputation for appealing to fly-by-nighters. You go for three days and you are in and out again. Three days is useless in trying to get to know a potential developing country market.

CIDA has been badly burned by many renewable energy companies who created expectations. They got $10,000 starter studies, then $100,000 feasibility studies and that's as far as they could go. After the $100,000 feasability study they realized that they didn't have the legs to keep going and CIDA had spent the money. They had created expectations in developing countries that never got as far as even a demonstration project, let alone developing a real market. So you are going to have some problems over at CIDA.

CIDA, the World Bank and many of the other development banks are not really interested in small projects. CIDA's major business is multi-megawatt hydro. Anything less than a million dollars usually doesn't interest them.

The programmes in these areas are for proven technology. The third world is no place for your firm to undertake its commercialization phase. Also, a technology proven in Canada or the US, doesn't seem to mean a technology proven in the Carribean or Kenya.

The next decade will be the time for extended field application to test and verify the long term reliability of wind systems.

What are some of the other problems that relate more specifically to wind?

It's a bit touchy in many developing countries because we don't have much information on wind regimes. There is a lot of work to be done there.

I would also say forget about very large machines. They are totally out of the financial reach of developing countries. In addition, in most cases they require maintenance and supervision far beyond the capabilities of the developing country's personnel. This is especially true if they are to survive harsh wind conditions that exist in many tropical countries. I consider a large machine to be anything in the 200 kilowatt and over range.

Small wind generators have an advantage over large units, not only because of cost, but because they are manageable. Developing countries want technology they can manage themselves. There are limits in developing countries, even to the use of small wind generators. No matter how great their success in developed countries, the market demand is not proven from a developing country point of view.

We may sit here and all think there is a fantastic market out there. However, when I was in Thailand recently, I was told by both the private and public sector that if I thought there was such a great market, then I should pay for the marketing study myself and come back when I'd concluded that there was a good market. Then we could talk business. If we think there's a good market then we are going to have to find it ourselves. They are not going to find it for us and do the work for us.

The immediate need in developing countries, I would say, is not for wind-generated electricity, but for simple, cheap, wind-water pumpers.

I will use the Thai example again. There is a local manufacturer of wind water pumpers in Thailand who sells 200 units a year. That's a local Thai manufacturer. The technology is relatively well-known and easily understood in comparison to wind electrics.

For a technology transfer situation, the manufacturers of wind generators will likely be restricted to a very few of the most industrialized and developed third world countries. You are going to have to go to the most developed of the developing countries. No point in going to the Sahel. Even these countries will be unable to produce machines larger than 200 kilowatts. However, it is reasonable to expect that the assembly of the system and the fabrication of the tower and generator housing could be done in local shops. So we're talking local assembly and fabrication of tower and generator housing.

The biggest hurdle is financing.

You could do some third-party financing if you want to risk it. Local institutional financing through state or local utilities is sometimes available.

You are going to be attempting to displace diesel generators. However, as I've indicated, institutions such as the international development banks, CIDA and so on, are not all that thrilled with renewables. Consequently, I would suggest the thrust of your R & D efforts should be in the area of getting capital costs down.

That's all I want to say on the topic. I do, however, want to make one other small speech which relates to some things that have a great amount of impact on what's been happening in the renewable energy sector in Canada in the last month. I think that's part of the reason why this association is here.

We've got to get out and lobby the government. There have been some very disturbing things take place lately, particularly, of course, in terms of the NRC R & D cuts.

I think that we haven't seen half of it yet. I received a very disturbing letter yesterday from The Honourable Minister of Energy, Pat Carney. I just want to read two sentences to you - incidently this letter is written to a person in the renewable energy sector - :

"We are maintaining support in a number of areas: coal and tar sands for example, which we see as being of high priority for Canada's energy future. In the present economic climate, we must recognize that we cannot make government expenditures in longer term areas, or areas of relatively low energy priority, on the scale which was possible in the past."

Well, if you read between the lines it sounds like the low energy priority is the renewable energy sector.

I notice that we have Don Strange and Jack Cole from Energy, Mines and Resources sitting in the audience. There's no point in going and talking to them with bleeding hearts and feel that you've done your bit, because they're already on side.

We've got to get letters out to Carney and Mike Wilson and indeed, your own Member of Parliament, if this association is going to have a second annual meeting.

I'll take questions now.

Q. You mention the small and medium companies. What's the cut-off? What is a small manufacturer of wind machines?

A. Small and medium sized companies? I would consider our company to be a small company. We've done some work in the international area, but it's only been through some exceptional circumstances. We've done some projects which were initiated by External Affairs and two or three by CIDA. Any efforts we've ever made on our own to go into the joint venture, technology transfer market have proven to be far too long term. We're talking, as I said, two years and we just don't have the manpower to sustain a Canadian and an international operation.

Are you asking me in terms of the number of employees or volume of business?

Q. Volume of business. You use solar panels...?

A. Do you know the company, Cambrian Engineering? Right now they are getting into the Jamaican market in concentrated collectors and I was told by their Vice President of Marketing two weeks ago that they find that their resources have been absolutely stretched to the limit. That would be a medium company. You know the amount of business you do in a year doesn't really tell you too much. It's how much of it is in the black.

Q. Do you consider domestic deployment as an essential pre-requisite to international marketing? Domestic deployment? You've got to sell it at home before you can sell abroad.

A. I would agree. Now where are you going to sell it if you are a Canadian company in Canada? You know, other than, as Thermax indicated, perhaps the tinkering market. There's certainly no incentive. The buy-back rates aren't very attractive. I would suggest that for Canadian companies, maybe one of the best markets is the United States right now. But you've got to have a proven technology at home before you can go abroad. Then, when you are abroad, you've got to start all over again and prove it there.

Q. What are your product lines?

A. We don't have any product lines. We sell services. We'll market anybody's technology in wind, biomass, photo-voltaics, small hydro. There are two streams to the company, one which does project management and the other does consulting.

Q. Would Canada have a chance in the European market?

A. I'm not familiar with the European market.

COST-COMPETITIVE DESIGN ADVANCES IN A 125 KW VAWT

Alexander Printzios, ADECON Energy Systems Inc.

Wind, as a renewable source of energy, has been utilized for centuries. In Europe in the 17th century, some 9,000 windmills were in use in Holland and an equal number in England, but the first serious attempt to develop an electric utility wind turbine wasn't made until the 1940's in North America. It wasn't until the 1970's that wind power was acknowledged as the one form of renewable energy that is closest to commercialization. However, the intensified interest in the development of wind energy arrived in the 1980's with the introduction of federal tax credits for wind energy investment in the United States and particularly in the State of California.

The challenge that is facing the wind energy industry in North America is this: 'How do we manage to sustain the momentum generated through the investment community with tax benefits coming to an end at the end of next year?' It is clear that the long term growth and advancement of wind energy relies solely on its ability to compete with other sources of power generation.

The ADECON 125 vertical axis wind turbine was specifically developed to meet this challenge of long term economic generation of electric power. And, ladies and gentlemen, what an exciting challenge this is indeed!

The ADECON 125 is a 100 per cent Canadian developed and manufactured product. All components, from the blades to electric generators are produced in Canada and each unit represents 350 person-days of work. The ultimate objective of our challenging two year development project was simply this: to develop a system which would ensure not merely a good return on investment, but an excellent return on investment.

Now to proceed to the more technical aspects of this presentation.

The ADECON 125 is an intermediate size wind turbine designed to produce on the order of 125 kilowatts of electric power compatible with a utility grid. It is similar in configuration parameters to a prototype, 10 meter research turbine with certain configuration changes aimed at a reduction in total installed cost. The emphasis throughout the development stage was focussed on component cost reduction rather than selection of optimal configuration.

Rated power of a wind turbine can be readily manipulated by raising or lowering the rated windspeed. Therefore, swept area is a more appropriate parameter to convey accurate information about the capability of a wind turbine.

The 17 meter diameter rotor has a swept area of 283 square meters with a maximum power of 125 kilowatts. The power loading is 440 watts per square meter.

The two blades, which are the energy extracting members of the system, are fabricated with multi-element extruded aluminum shapes. This unique feature results in considerable reduction of the overall weight. The weight of the blade itself is 11 kilograms per meter compared to 27 kilograms per meter in the presently available blades. This drastic reduction translates to lower extrusion costs, production capability at local extrusion mills and a reduction of the dynamic effects.

The 24 inch chord blade consists of four extruded aluminum sections. The joins between these sections, subjected only to sheer loads, are bonded by a flexible adhesive bonding normally used in the aerospace industry for structural applications.

The central column is a 1.2 meter square steel lattice structure. The size was chosen as a compromise between bending strength, lateral natural frequency and aerodynamic losses. While the cost of this central column is less than a quarter of the cost of a tubular column its weight is reduced by a factor of six.

The turbine assembly is supported entirely by an external, rigid frame, lattice structure. The choice of the rigid external frame as a support mechanism evolved after a trade-off of the various factors. As as a structure, the rigid external frame is more costly than guy wires. However, the external frame eliminates the axial load on the upper bearing and consequently reduces the cost of some components. In particular, the upper bearing is sized to carry only the radial load and hence is a low cost item. The resulting reduced load on the lower end of the column allows it to be carried directly on the transmission, thus eliminating the lower bearing, one coupling and the intermediate shaft. The rigid external frame also reduces foundation loads and consequently the cost. In addition, the external frame makes it possible to raise the rotor equator higher, from 52 feet to 84 feet and hence to increase the energy production by approximately 25 per cent.

Although the incorporation of these innovations has resulted in the most cost-effective and competitive system in today's market, these innovations are only a first step, so to speak, on the road to further cost reduction and technological advancement. This, of course, is in line with the philosophy that only a few innovative steps should be taken at any one time to minimize technological and financial risks, and to ensure that the road to further advancement remains as smooth as possible.

Commercial viability of the vertical axis wind turbine technology is dependent upon its ability to compete with other energy resources and particularly the non-renewable ones. The establishment of the usefulness and the technical feasibility of the ADECON 125, its the degree of success in penetrating the energy market, is proportionate to the cost-effectiveness of the system as related to its energy generation capabilities or its cost advantage in relation to similar commercially available systems.

Continuous and expanded development in the wind energy industry is essential if we are to meet tomorrow's challenges fully prepared. This new industry, which is still in its infancy, has a great potential on the international stage. And this we can not afford to overlook, Ladies and Gentlemen.

A good example of this new industry's market potential can be found in the flourishing California market. It presently enjoys high growth with over $700 million sales in 1984 and projections reaching some $1.6 billion dollars in 1985. The overseas market, although still in its initial stages of development, shows healthy signs indeed of development and expansion. This, in particular, as the technology increases in efficiency, performance and volume production together with appropriate marketing strategies.

It is at this point interesting to note that European manufacturers of wind turbine systems enjoy a leading edge in this competitive market. It is just as interesting, and perhaps more so, to note that generous subsidies from their respective governments have resulted in the European manufacturers assuming a dominant position not only in the North American market, but in the developing countries as well.

That Canada has a technological leadership in wind energy development is indisputable. But whether or not this leadership quality eventually translates into tangible economic benefits for us all will depend on the further encouragement and support of this exciting new industry, an industry who's full potential has yet to be disclosed.

Thank you.

Q. Does your machine have a price tag yet?

A. Yes. The system right now, with limited production for one to five units, will cost between $110 to $125 thousand Canadian dollars, including installation.

Q. Where will that put you in relation to your competitors?

A. As far as we know, for the two main manufacturers of vertical axis wind turbines that are our competitors in producing a system of similar size in the United States, their installed cost is between $250 and $340 thousand US dollars per unit.

Q. What sort of a wind regime is this machine most appropriate for?

A. Well, it is mainly for a utility grid application. For wind regime? It was designed for medium wind regimes mainly. For instance, at a 16 mph average wind speed it will generate approximately 325 thousand kilowatt-hours per year.

Q. What is the rated wind speed for the 125 kilowatt output?

A. It's 36 mph.

GOVERNMENT POLICY AND PROGRAMMES

"A POLICY REVIEW"

D.L.P. Strange, Director, Renewable Energy Division
Energy, Mines and Resources Canada

PROLOGUE

Now I know that there has been a lot of concern lately with regard to the federal government's position on wind energy and renewable energy in general. I am sure that many of you would like to see a firm commitment made on this issue by my department.

Unfortunately, today it is rather difficult for me to make a real commitment on behalf of EMR. There have been cuts, as you know, in the NRC's work in renewable energy, including wind. At EMR, a review of all energy programs is underway. We have embarked on a round of consultations with industry and other levels of government. That is in part why I am here today. We need to know what should be done in the wind energy area, and in particular what role the federal government could play.

Today there are, I feel, several key issues facing the continued accelerated development of wind energy in Canada.

- how much energy can the wind realistically provide?
- when will we see cost-effectiveness in Canadian wind machines?
- what is the best strategy to attain cost effectiveness?
- in terms of national policy, what importance should we attach to developing wind energy - and what should be the government's role?
- what should be our priorities? - large scale, medium scale, or small scale systems?
- how do financial investors view this new energy development?
- what does the industry need in the way of support?

I am going to give you a brief overview of my thoughts to help launch a much needed dialogue on these issues.

INTRODUCTION

As you know, Canada is a country with a huge area and a small population and consequently it is easy to show that the theoretical potential for wind energy is quite large in relation to total electricity demand. For example, there is a potential of at least 50,000 MW that could be developed in those areas lying within 100 miles of existing transmission lines. But not even a small fraction of this potential will be developed if wind energy is not reliable, efficient and cost-effective.

Tracing the evolution of wind energy projects in which my department, Energy, Mines and Resources, has played a role, we would start with the 1977 Canada-Prince Edward Island Agreement. This agreement helped support the establishment of the Atlantic Wind Test Site (AWTS), officially opened in 1981. More than 10 units have been tested there so far. The largest unit to be tested is a 500 kW DAF Indal, bought by NRC.

Further federal government action in the renewable energy area beyond R&D activities began in 1978 with the announcement of a comprehensive package of renewable energy programs.

The federal government annnounced negotiated cost-sharing agreements with the provinces for the demonstration of technologies and applications in the renewable energy and energy conservation areas. This was known as the CREDA program. Roughly $1.5 million has been spent under CREDA for wind energy projects, amongst which was the highly successful demonstration for remote applications, the Wind/Diesel hybrid system in Sudbury. This installation is still an important working model for Ontario Hydro, the National Research Council, DAF Indal Ltd. and the Ontario Ministry of Energy.

Another program of interest to the wind energy community is the Remote Community Demonstration Program (RCDP) which was introduced in 1980. RCDP is designed to encourage communities not connected to the main electrical grid or natural gas supply system to investigate their off-oil opportunities and then to fund selected demonstration projects. Under Phase I, nine pre-feasibility studies related to wind energy have been done or are still underway. Phase II is expected to fund some demonstrations during the next four years.

On March 31, 1984, the CREDA program with the provinces was due to expire. A decision was made to wind down the existing CREDA and initiate a new national demonstration program. The decision to launch ENERDEMO-Canada was announced in January 1984 and I will discuss later the wind energy aspects of ENERDEMO-Canada.

While those efforts were in progress, the federal Research and Development efforts have focussed on the design and development of vertical axis (Darrieus) wind machines. That work was carried out almost entirely by the National Research Council. Yesterday's presentation by Marc Chappell made us conscious of the immeasurable efforts and energy (and this was all renewable energy I am told) put out by him and his co-workers toward the wind energy cause. They have produced meaningful results. Just to mention a few of their projects: the 230 kW turbine on Ile de Madeleine, the five 50 kW Darrieus machines installed across Canada in several provinces, the wind resource monitoring in conjunction with the Department of the Environment, the testing of wind energy equipment and many other related projects.

NRC also represented the federal government's interests in its largest project, the design, construction and testing of a 4 MW turbine. Hydro-Quebec and NRC are cost sharing the construction of project EOLE for a total cost of $35 million.

This list of activities and programs done under the federal and provincial government's umbrella should not diminish the importance of the work accomplished by numerous other organizations such as universities, industries, electric utilities, research groups, and individuals interested in the development of the wind energy potential in Canada. Their work will become more and more important as this technology develops.

The development of wind energy is at a very important and perhaps critical stage. Strategies have to be developed and implemented. The wind technology must demonstrate the potential of competing with other energy options and conventional energy sources in order to establish its place in the energy market. Realistic goals have to be defined; and this is the time to begin consultation between the many groups and individuals involved in this business. We need to have a consensus of views and expectations in order to plan our respective activities. CANWEA is obviously a major step in this direction.

COMPARISON WITH THE WORLDWIDE WIND ENERGY ACTIVITIES

How does Canada compare right now with the rest of the world in wind energy development? Certainly evidence of wind energy potential can be seen in California where a recent surge of windfarm development within the last three years has resulted in the establishment of over 1500 MW of power purchase contracts with the two major electric utilities. Numbers show that the worldwide wind turbine market increased from $122 million in hardware value in 1982 to $191 million in 1983. The forecast for 1984 calls for hardware value to reach $410 million. In terms of nameplate generation capacity, installations have increased from a level of 95 MW in 1982 to 194 MW in 1983. The outlook for 1984 is for over 440 MW to be installed, representing a four-fold increase in generating capacity in two years for worldwide installations. The bulk of activity is taking place in California and according to the California Energy Commission, the state's wind industry generated 43 million kilowatt-hours of electricity in 1983. At certain times and on certain days, wind machines in California's passes feed in 1 percent of Pacific Gas and Electric's total electrical output.

California is likely to remain the clear leader in wind energy development for some time, as the conditions which have led to that development such as fossil fuel dependence, high electricity rates, legislated power purchases policy, favourable wind regime, and attractive fiscal incentives, do not prevail in many other locations and certainly not in Canada. We can safely say that we are in the demonstration phase of a technology which is already in commercial development elsewhere. What then are the commercial prospects for wind energy in Canada?

FORECAST FOR CANADA

In Canada, the primary market for wind energy in the near term will be applications in remote locations due to the high cost of electrical energy from conventional sources such as diesel oil. Primary power for remote instruments and special-purpose applications where stand-alone wind systems could serve as small power generators or battery chargers will also provide a first market. The harsh environment specific to remote sites in Canada requires improvements to most existing wind turbines in order to stand up to these climatic conditions. We expect that demonstration projects will be an essential step in the development of this specific market.

A second major market in Canada in the longer term may be grid connected windfarm applications. Good wind regimes plus relatively expensive conventional energy production costs may make some parts of Canada, such as the East Coast fertile areas for wind farm development. Current utility surplus capacity of course mitigates against rapid development of any new grid supply in Canada.

The agricultural as well as the residential sectors will represent a very limited market for wind energy if we assume that Canada will follow the same pattern as the United States in this area.

Another major trend in the market has been the growth of installations for intermediate-sized turbines, that is, turbines with nameplate ratings between 50 kW and 500 kW. During early development, most wind farm developers favoured smaller turbines. Individual investors could buy these turbines because of the low, per unit cost. Currently, as a result of innovative financing schemes, investors can turn towards the intermediate-sized turbines which have a higher unit price. The choice between small and intermediate has shifted from one of low initial economic purchase price to one of longer-term economic performance cost.

The average size turbine used in commercial application for 1982-1984 has evolved as follows:

- 1982: 35 kW (nameplate)
- 1983: 55 kW (nameplate)

- 1984: 70 kW (nameplate)

Current evidence shows us that on a cost per kilowatt-hour output, the optimum economic size seems to fall within the intermediate turbine size.

Large turbines, that is the multi-megawatt size, have experienced multiple problems and, as they are still in the prototype stage are still quite expensive. It appears that costs cannot come down without volume production. The perceived risk is a lot higher with large turbines than small ones. However, continued efforts in the U.S., Great Britain and Europe show us that the development of these large scale machines is still being strongly supported. In Canada, Project EOLE will allow us to get more information as well as experimental data on the possible cost reduction achievable by large vertical axis wind turbines.

EMR PROGRAMS

Based on this short analysis, we can expect to see wind energy systems going up in remote locations as fuel savers and near main electric grids in wind farm developments. We have already in place two major programs that are perfectly suited for these applications.

The Remote Community Demonstration Program as previously mentioned is designed for communities not connected to the main electrical grid. Nine pre-feasibility studies have been done under Phase I (4 Newfoundland, 2 Quebec, 1 Ontario, 1 Northwest Territories, 1 British Columbia). Phase II which started October 1, 1984 is expected to fund some demonstrations of wind machines. We have already committed ourselves to one such demonstartion project. We are looking for good project proposals.

We hope with this program to be able to demonstrate not only the cost-effectiveness of wind energy systems when used as a fuel saver but also their reliability in a harsh environment. If that latter point can be achieved, this will be a great accomplishment for wind systems and many doors will open to the commercialization of wind systems in remote locations.

The second major program is ENERDEMO-Canada. It is designed to demonstrate the value of new technology in renewable and energy conservation applications for all sectors of the economy. While this program is designed for the demonstration of all renewable energy options, we have recognized the relative importance of wind energy within other renewables and consequently we are structuring a sub-program to tackle the wind farm sector. This sub-program of some $1.1 million will help demonstrate wind farm applications in a Canadian context. We are in the initial process of structuring the sub-program and expect to issue RFP's within a few months. Of course, installation of individual units is also eligible under the overall ENERDEMO program.

Those two demonstration programs will provide to Canadian industries and us experience and concrete results but moreover for you, as industrial players, it will give a solid base on which to tackle the export market. Many other programs are also available to you, IRAP, PILP, PEMD and IRDP to name only a few. It is up to you to explore the opportunities available to you through these programs.

Third Party Financing of Wind Installations

J.C. Shepherd

Blaney, McMurtry, Aarons & Watson
Barristers and Solicitors

This paper will deal with methods of using tax incentives to make third party financings more attractive, which until very recently were an area of great potential for the wind energy industry. However, on October 25th, the Ministers of Finance and Revenue jointly announced that they would be suspending the giving of advance tax rulings for limited partnerships and other joint venture financing arrangements. In case the connection is not immediately apparent, third party financing of alternate energy projects almost invariably uses either a limited partnership or joint venture structure.

To clarify the import of this, at the Canada Tax Conference in late November the head of Corporate Rulings for Revenue Canada said, both privately and in the public sessions, that the action of the Departments of Finance and Revenue was specifically directed at third party financing of capital asset acquisitions. Their intention is to signal to the investment community that they are looking closely at these transactions, and reviewing their acceptability. You must understand that this does not mean the rules for these transactions are changed. The rules clearly allow this sort of structure. However, for many would-be investors, this signal will be enough to put them off. Result - a weak market until government policy is clarified. (Department of Finance people at the tax conference said that they have set up a group in Finance to review these financing mechanisms, and the result may be legislative changes as early as the spring budget.)

Given this background, this paper will try to concentrate on concepts of tax-related financing vehicles, to give a general understanding, which may even be as useful six months from now as is today.

The first concept here is that of the "third party". A tax-based financing rests on the fundamental premise that a particular transaction - such as acquiring a WECS - carries with it certain tax advantages, and a third party investor trades his cash for the tax breaks. In effect, the federal government makes a small investment in the deal, somewhat involuntarily. (In view of their recent missile attack on the NRC's Energy R & D program, this may seem like simple justice).

A digression is necessary here. Some of those who would buy wind energy equipment anyway do have real tax problems, and could use a tax shelter of their own. If you recognize that in dealing with them, you may find that the attractiveness of the transaction can be increased by emphasizing the tax benefits. Of course, the impending change of policy by Finance and Revenue on third party financings would not affect the purchaser's own tax breaks. As well, often the tax incentives to the purchaser are better quantitatively than those which can be directed to a third party financier.

The second general concept is the difference between tax shelters and tax enhanced investments. Although many of the same structuring methods are used in both, the ultimate goal of each is different, and the investors are entirely different groups.

In a tax shelter, the investor is never out of pocket (except for perhaps a short period of time). The tax incentives, plus any guaranteed revenue from the project, will always exceed the cash he has paid out. There are two corollaries to this. First, it is generally the case that the investor is asked to put up money on, say, December 31st, in the expectation of getting that money back from RevCan on April 30th. That short term negative cash flow is not normally considered detrimental, although even there sometimes the people structuring tax shelters try to minimize this. Second, although there is no negative cash flow there is usually a negative credit flow, in the sense that the investor will pledge his creditworthiness to a stream of future payments. The intention is that that stream of future payments will never have to be made because it will be covered by revenue, but the liability will still be there. The bottom line, though, is that in a tax shelter you must be able to say to the investor that the tax savings create a net improvement in his present and ongoing net cash flow.

From the point of view of a wind installation, it is very difficult to create a true tax shelter with a third party financier unless the installation qualifies as research and development. It is possible in some cases, but usually the economics just are not there, given the size and timing of the tax savings.

The more common method of third party financing is a tax-enhanced investment. This is an investment in which the structure is designed to maximize the tax incentives, not so that there will be a positive cash flow, but so that return on investment for the investor will be increased. This can be done either by reducing the net tax cost along the way, or more commonly by increasing the first year tax saving so that the total amount of cash actually invested, on an out of pocket basis, is reduced. If you can structure your first year payments so that the actual amount of cash that the investor has to pay out, aside from amounts that will be financed by the bank or others, is lower, then on the same revenue stream the percentage return on investment is higher. Reduce the cash out from $200,000 to $100,000, and an annual net cash flow of $20,000 is a 20% return on investment instead of a 10% return on investment. This can make all the difference to the viability of the investment.

The key difference between tax shelters and tax-enhanced investments is in who will invest. The tax shelter investor is anyone with money - doctors, dentists, executives, etc. They may look at the details of the project planned, and nod sagely when it is explained to them, as if they understand, but all they really care about is the computer-generated spreadsheet headed up "Cash Flow Projections" which shows that they are never out of pocket one dime.

On the other hand, the person you want for the tax-enhanced investment really is looking for a place to invest his money. The intrinsic worth and viability of the project are of vital concern to him, since its failure would mean a financial loss for him. Rarely will this person be a doctor or other professional - he'll be an entrepreneur, or an experienced investor of some type. While the numbers are important to him, it is the return on investment figure that is the true key to unlocking his wallet.

Some years back a feminist novelist, Erica Jong, coined the word "zipless" to describe a certain type of relationship - one with no emotional or other entanglements, simple, direct, and fundamental in nature. The third general concept of tax related financings is that investors want the deals to be "zipless". The promoter, usually the vendor of the products being financed, has to put all the components of the transaction together for the investor, so that his role is no more complicated really than buying a bond and clipping the coupons.

This isn't just a question of responsibility for the paperwork. All business aspects of the transaction are worked out in advance. In the sale of a WECS, this involves at least the following:

(a) getting an agreement from a user to use and pay for the power generated on set terms;

(b) installing the system and guaranteeing its performance;

(c) finding an institutional lender to provide partial funding to the third party investor;

(d) managing and servicing all technical and financial aspects of the project during its lifetime, usually without further payment;

(e) providing ironclad assurances (such as legal opinions) as to the availability of the various tax incentives; etc. etc.

The investor will generally not even talk to you until the "package" is in place and he can see exactly what he's buying. You must understand clearly that the investor does not want to do a business deal, with negotiations, etc., etc. He wants to purchase an investment, so you have to create a complete investment for him to buy.

The fourth concept is called "loading". In order to maximize tax incentives, you want to structure your transaction so that most of the costs are incurred by the investor in the first fiscal year, usually by December 31st. This increases his up-front tax savings, and therefore increases the amount of the initial cheque he will be willing to give you. There are many ways of doing this, typically involving increasing the initial price and reducing the subsequent charges. For example, you may normally try to keep your purchase price relatively low on a particular product, expecting to make much of your profit on normal servicing requirements over the next ten years. This makes good business sense, but bad tax sense. Instead, you could sell that same product with a ten-year full warranty, increasing the price accordingly. The price may go up from $200,000 to $300,000, but with an increase in tax savings - plus some careful leveraging, discussed below - the out-of-pocket cost on day one may be much less.

The fifth concept is "characterization". In most situations, you will try to structure your transaction so that each component of the money the investor puts in will be characterized as a high-tax-incentive amount. This usually means receiving amounts as design, consulting or other fees rather than as part of the purchase price of a capital asset. Commonly the vendor will try to receive all of its profit as fees of this sort, since such fees give the investor the greatest tax savings. On the other hand, in those few situations in which the tax breaks for buying a capital asset are higher, you would set up a structure in which everything is part of the cost of the WECS.

Finally, the sixth concept is "leveraging". In putting together a package for an investor, you want to minimize the extent to which he has to reach into his own pocket. In order to do this, you look for persons who will lend the investor the money to make his investment. There are three typical sources:

(a) First, an institutional lender such as a bank may lend, say, 50% of the total price. Remember that the borrower is someone with money, not an impecunious energy purchaser.

(b) Second, government grants and loans can account for a substantial portion of the price in some places, and it is up to the vendor to put them in place.

(c) Third, if the price has been increased through loading, some or all of that amount can be lent back to the investor by the vendor, to be repaid over time.

Look at a simple example. You are going to install a $200,000 WECS in Prince Edward Island, financed by a third party. Through effective loading, you increase the price to $300,000, the last $100,000 being consulting and other deductible fees. This package means your investor has immediate tax savings of, say, about $90,000. He therefore has to find at least $210,000 more to fund the project. You arrange with a bank to lend him $150,000 at a favourable rate (and you may have to pay a buy-down fee to get that rate, by the way), and he has $60,000 left to find. However, you have that extra $100,000 that really covers your servicing responsibilities for ten years. If you lend $80,000 of that to the investor, repayable over ten years, you are still ahead $20,000 but the investor now has a positive cash flow of $20,000, and everyone is happy.

That is but one example. There are many others. So, while unfortunately we have to wait at least a few months to know the exact rules of the new game the government will be setting up, in general terms the use of tax incentives to enhance the value of a wind energy investment can be a profitable exercise.

(One aside should be made before concluding. Owners of alternate energy producing assets - such as windfarms - who operate those assets in order to sell the power generated, are only entitled to a 6% capital cost allowance rate under the Income Tax Act, one of the least attractive rates for any asset under the Act. In this period where the Department of Finance in making many changes to the Act, the newly-formed Canadian Wind Energy Association might consider making representations to Finance to get this CCA rate increased. This would greatly increase the viability of third party financing for certain types of wind installations, such as commercial windfarms in remote locations.)

NOTES FOR THE SEVENTH ANNUAL WIND ENERGY SYMPOSIUM

Mr. Andy Watson, M.P.P., Parliamentary Assistant
to the Ontario Minister of Energy

Harbour Castle Hilton Hotel, Toronto,
Tuesday, December 11, 1984. 12:00 noon

Introduction
(Vince Lacey)

Ladies and gentlemen. Now that you've all had a chance to finish your soup before I got a chance to start.....

First of all, I want to welcome you all to this luncheon of the Seventh Annual Wind Energy Symposium. We certainly appreciate all of your support in being here, supporting the symposium, and supporting the foundation of our new Canadian Wind Energy Association which got officially going last night.

I think we have a very interesting lunch lined up with Mr. Andrew Watson as our guest speaker.

At this time, I would like to introduce the head table which consists of the Steering Committee of the Canadian Wind Energy Association. This is their 'last hurrah!' as we say.

Starting on my left, we have Bill Stewart at the Ontario Ministry of Energy. Next to him, the 'Rev.' Marc Chappell (Thank you bishop Lacey - M.C.). Next to Marc, of course, Monique Carpentier of the federal department of Energy, Mines and Resources. On my immediate left, Mr. Malcolm Lodge of Resource Ventures Inc. and the Institute of Man and Resources - the man who wears both hats. That's not to suggest that he thinks he has a big head, it's just a question of responsibility! On my immediate right, our guest speaker, Mr. Andrew Watson. He is followed by Nicholas Teekman of DynamoGenesis Inc. who has really done a wonderful job in organizing this show. David Hoffman of the World Communications Inc. Sorry, World Wind.....I do subscribe David, (He does - D.H.) I just don't read the title. That's true!

At this time, I would like to make a special note about the effort that has been made by the chairman of the Steering Committee of the Canadian Wind Energy Association, Monique Carpentier. In spite of her size, she has managed to wrestle us all into submission and kept us on track, kept us going to the meetings and completing the objectives as outlined. I think that without her authouritative stance in some of the meetings, we wouldn't have accomplished what we did. So I'd like to ask you all to join me in a special thanks for Monique, for all your efforts.

We are, I think, especially honoured today to have as our guest speaker, Mr. Andrew Watson. Mr. Watson has been the provincial member of parliament for the riding of Chatham-Kent since 1978 and more recently, has been the Parliamentary Assistant to the Minister of Energy since September of last year. So, with that said, it is my privilege to introduce to you Mr. Andrew Watson.

Presentation

Thank you very much Mr. Chairman, head table guests and Ladies and Gentlemen.

It's a pleasure to be with you today. I guess I am reminded somewhat of the politician who got up to address the people at a penitentiary. He didn't quite know how to address them. So he was a little scared in how he should say and what he should say. So he got very formal and started off by saying: 'Ahem, fellow countrymen.' Well, a little twitter went through the crowd because these people had all temporarily lost their citizenship and really weren't fellow countrymen anymore. He realized that, so he pulled himself up again and says: 'Dear friends.' Another twitter went through the crowd because how could anybody that passed a law that put them behind bars ever refer to them as friends? So finally he said, "Well, forget that, I'm just glad to see so many of you here!' Got through to the head table here. Good!

I want to thank you for the opportunity to be with you here today, and to congratulate you on your birth as an organization.

I understand this is the 'last hurrah!' at the head table for the Steering Committee. Only the future knows the significance of being a charter member of an organization such as the Canadian Wind Energy Association.

You are to be commended for your aims and objectives, and I want to wish you well as you venture into the future with your new group.

I hope that you realize that there is some danger in inviting a politician to be a luncheon speaker at a conference concerning wind, a couple of weeks before Christmas.

After all, the kind of wind that politicians are used to dealing with isn't the same kind of wind that you have been talking about. I expect that the political wind comes with a much higher temperature in the form of hot air, than does some of the installations that your members are dealing with in remote areas of the north. I suspect that the wind that you deal with can be scientifically measured, and I doubt if the hot air that many politicians continue to puff can be measured at all much less scientifically.

One of my first thoughts concerning wind when I knew that I was coming to speak to you today had to go back to the old farm windmill - that wonderful device that pumped water on many of our Ontario farms for many years before electricity arrived, and that same device that was the subject of many four letter words, when there just wasn't enough wind to turn that wheel to pump that water, and muscle power or manpower had to be substituted on the end of a pump handle to pump water for those cattle.

And now we have newly designed windmills manufacturing electricity which pumps water. In a way, I guess, we have come full circle, and I am reminded of the old saying, "Blessed are those that go around in circles, for they should be known as big wheels."

Big wheels may not be the term that you like to have yourself referred to as, but you are the people who are responsible for the level of technology that this industry has achieved to date, and who will be responsible for the improvements and advances that it makes in the future.

The wind may be the driving force which makes the big wheels and little wheels turn, but you are the driving force that will make the industry succeed in the future.

My first recollection that wind could be useful had to come from the old fanning mill, when I helped my father clean up the grain for spring seeding. I am also reminded of running the blower on the thrashing machine as we used to build a straw stack, and I would get properly blasted with a different kind of wind when I turned the direction of the blower the wrong way, and whoever happened to be stacking on the straw stack got properly blasted with straw from the blower on the thrashing machine.

But I have grown up since then. Some of you will wonder how much when I tell you that for the past ten years I have owned an ice boat, and what a thrill it is to glide along on the ice on Lake St. Clair or the Thames River at a tremendous speed with what seems to be little or no effort.

During that same ten years, the priorities and the programs of the Ministry of Energy have evolved, and have necessarily been very broad in their scope. The oil crisis of 1973 was undoubtedly the catalyst that speeded up many things with regards to energy in this country, including the formation of our Ministry, and the realization by some of you that wind power was one of the sources of energy that could be looked at as something more than a hobby, or a dream.

The world has adjusted to the OPEC cartel and although things are far from stable in the Middle East and in the world of oil supplies, the situation is not as critical as it once was.

We, in the Ministry of Energy, are reorganizing internally, and I am sure that this will manifest itself so far as groups like yours are concerned in what we do to support industries like yours.

I mentioned earlier that in the early years of the Ministry of Energy, we had a very broad approach which tended to serve any and all types of alternate energy forms.

As we move into the future, we will be more interested in specific projects and the manufacturing of specific energy saving equipment that will not only conserve energy, but show a positive result on the financial books of the user.

A great deal of the technology advancements in the future will be the responsibility of the industries interested in that particular form of energy.

We believe that we have a sound base in this province and country for that type of technology, and as governments gradually withdraw, the void will be filled by the entrepreneurs that will accept the challenge and develop products that are both practical and profitable.

We think that there are advances to be made in terms of co-generation. We are well aware that some of the existing difficulties are related to the cost that the Ontario Hydro system will pay for co-generated electricity.

I know that there are serious discussions underway with Ontario Hydro concerning this subject, and that the new chairman of Ontario Hydro stated that parallel co-generation will become a priority in the post Darlington era.

I was pleased to participate at the opening of the energy trail at the Kortright Centre a little over a year ago, where wind power is playing a significant role. I was particularly pleased on that occasion to see the developments in wind generation, and although the parallel energy generation at that project was in connection with the photovoltaic cells and solar energy, the same principle for wind generation certainly applies.

I guess what I am saying is that some of the experimental and demonstration projects in which we have participated in the past, have been good and have been worthwhile. But the time has come to move into the marketplace and to market those types of equipment that can compete in the energy fields today. Many of the markets that the people represented here today will be looking at or beyond the boundaries of this province. Research and development are an important part of any energy program, and research and development must continue. But we must also be able to market the products that result from our research and development.

The winds of support from government for alternate energy sources are shifting. It is difficult, if not impossible, to know how far they will shift, or hard they will blow. It is easy to say we would like to substitute assembly lines for prototypes and a marketing strategy for a demonstration.

I have been somewhat vague today and I apologize for that. But like the vane on top of the old windmill, it turns when the wind changes. I hope that I have alerted you to the fact that the winds are changing, but at the same time, we want you and your industry to be helped rather than hindered.

As you form your new organization, I hope that one of the things that you will consider, as I am sure you have, is a means of liaising with both your federal and provincial governments so that neither of us get our windmills pointed in the wrong direction if a breeze starts to blow.

I invite you to make a point of keeping in touch. We do respect the opinions of your members who have given us individual counsel in the past, and we will respect the opinions of your new organization in the future.

Good luck and Merry Christmas, everybody!

VINCENT LACEY

Well, thank you very much, Mr. Watson. I think on behalf of all of us here, I want to say thank you for your support and your interesting observations and comments. I think they provide food for thought for all of us here in this room today.

I think, additionally, just a comment, that the reorganization of the Ministry of Energy, and your comments, remind myself, and the company that I represent, DAF-Indal, that it is time to get on with the commercialization process, so the message is clear and it is well appreciated. Thank you.

Now before we break up, I do want to remind you that we have a very interesting afternoon lined up with papers from the utility perspective, starting off at two o'clock sharp with a presentation from Albert Watts, with a review of the wind energy R & D activity at IREQ and that will be followed by papers from Trans-Alta utilities and also from Quebec Hydro. After that there will be an open meeting of the Canadian Standards Association, so I expect to see you all there. Thank you very much.

UTILITY TOPICS

RESEARCH ON WIND ENERGY AT HYDRO-QUEBEC

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PRESENTED AT
The Seventh Annual Wind Energy Symposium
Toronto, December 10 and 11, 1984

ABSTRACT

Hydro-Quebec, through its institute of research IREQ, has been actively involved in wind energy research since 1975, its main interest focussing on the development and utilization of large-scale Darrieus wind turbines. Analytical and experimental studies have been conducted on the various technological aspects of this type of aerogenerator. The paper briefly describes these studies and presents some of the results obtained. Special attention is given to Hydro-Quebec's two major projects on wind energy: the development and testing of a 230-kW Darrieus wind turbine on the Magdalen Islands, and the Eole project involving the design, construction and testing of the world's largest Darrieus wind turbine, which will have a capacity of around 4000 kW and a rotor 64 m in diameter by 96 m high.

1 INTRODUCTION

In Quebec, as in many other parts of the world, wind energy resources are considerable. This is one of the most flexible and tractable of all available energy sources, since the mechanical energy derived directly from the wind can be readily and efficiently converted to other forms of energy. Water pumping and production of electricity are the most common applications. There is ample justification for the widely held opinion that the wind can be used to meet a fair percentage of the world's energy needs.

Hydro-Quebec, through its institute of research, IREQ, has been actively involved in wind energy research since 1975. Two applications in particular are envisaged (Fig. 1): first as a fuel saver in the case of isolated grids to replace diesel generating units and, second, as a source of energy for the utility's main grid, almost entirely hydroelectric, which represents a long-term application involving a far larger harnessing of the wind resources in Quebec.

The objectives of the current research program are to promote the development and economic integration of wind energy conversion systems as a means of producing electricity and to support the local industry in the design and manufacturing of these machines. Because of the attractiveness of the Darrieus wind turbine, its relative simplicity and its potential for low-cost and large-scale applications, the research activities have become mainly oriented towards the development and utilization of this particular type of vertical-axis machine.

2 RESEARCH ACTIVITIES

Although the utilization of wind energy has been practised for centuries, the design of modern wind turbines and their integration into the electrical grid represent a major technological challenge. Manufacturers are required to build machines that are efficient, reliable, durable, cost-competitive and versatile while users must clearly define their specifications. Hydro-Quebec, for its part, has conducted analytical and experimental studies and thus developed considerable expertise covering various aspects of wind energy conversion systems. In doing so, it works in close collaboration with local industries, universities, government departments such as Energy and Resources Quebec and the National Research Council Canada, and, also, with foreign organizations.

2.1 Analytical Studies

The analytical studies performed so far cover a broad spectrum of subjects ranging from wind resources in Quebec, aerodynamic forces and performance, structural dynamics and power train dynamics to the assessment of wind power plants. These described in more detail below.

Like all other utilities engaged in this field of research, Hydro-Quebec has assessed the wind resources in the province and identified the most promising sites. Also, to support the design of wind turbines and their integration in the electrical network, it has developed analytical techniques for modeling wind characteristics such as seasonal variations, time and space variations, terrain effects, turbulence, etc. (Fig. 2).

Many analytical approaches for predicting the aerodynamic forces on the rotor blades and the performance of Darrieus wind turbines have been considered, developed and implemented on computer at Hydro-Quebec. The most well-known of these is the double multiple streamtube theory (Figs. 3 and 4).

Since the structure of wind turbine rotors is intricate and periodically solicited by aerodynamic forces, a thorough understanding of the vibration phenomena related to these rotating structures is essential for manufacturing reliable and durable machines. A method simulating all the elements of the rotor, including the support system and the power train, has been developed and implemented on computer. This approach makes use of the finite-element theory and the NASTRAN computer code (Figs. 5 and 6)

Variations in the aerodynamic torque influence the dynamics not only of the wind turbine rotor but also of the power train as well as the quality of the power injected into the grid. It is therefore essential for wind turbine designers and users to understand the dynamic behavior of the whole system for all the operating conditions. To this end, a simulation method has been developed which takes into account the following components of wind energy conversion systems: the aerodynamic torque, the rotor, the drive train, the electrical machine, the control system and the grid. Two types of simulation study have been conducted: one, using a numerical solution, was performed with the CSMP (Continuous System Modeling Program) computer code, the other, a real-time simulation, was done on an analog computer (Figs. 7 to 10).

The utilization of wind turbines as generating units in existing electrical grids raises many questions because of the intermittent and largely unpredictable nature of the wind, and electrical utilities find it difficult to evaluate their potential as a viable and economic adjunct to conventional electric power sources. Hydro-Quebec has developed a methodology which takes account of the characteristics of the wind, the aerogenerator, the electrical grid, the generating units and the service reliability level. This technique should be suitable for assessing both the capacity and the energy value of wind power plants in different generating systems as well as their penetration potential and total system costs (Fig. 11 to 15).

2.2 Experimental Activities

2.2.1 40-kW Horizontal-Axis Wind Turbine

In 1975, IREQ initiated a study of the feasibility of an autonomous electric generating plant for remote areas using a wind turbine coupled to a compressed-air storage system. A 40-kW, 10-m-diameter, horizontal-axis wind turbine designed by the Brace Institute of McGill University was selected for this project. The electricity produced by the wind turbine generator was used to drive the compressor motor and the compressed air was

stored in a 26-m reservoir at a pressure of 5 MPa. At the other end, an air turbine connected through a gear-box to a 75-kW electric generator converted the stored energy back to electricity. A specially designed control system assured the proper operation of the whole system and the quality of the power produced (Figs. 16 and 17).

2.2.2 Experimental 50-kW Darrieus Wind Turbine

In July of this year, a 50-kW Darrieus wind turbine manufactured by DAF INDAL was installed at IREQ (Fig. 18). The rotor, comprising two aluminum blades, has a diameter of 11.2 m and is 16.8 m high. It is mounted on a 5.8-m steel tower and held in position by three guy wires. The gearbox consists of a large gear and a pinion driving a 550-V AC induction generator at constant speed or a synchronous generator at variable speed by means of a static frequency converter.

Since the objective is to develop a flexible test facility for Darrieus wind turbines, the machine will be fully instrumented and modified in terms of studying the aerodynamic forces on the rotor blades, the structural dynamics of the rotor and guy wires, and the dynamic behavior of power trains and control systems.

2.2.3 Magdalen Islands 230-kW wind turbine

In 1977, Hydro-Quebec, jointly with the National Research Council Canada, installed a 230-kW Darrieus wind turbine in the Magdalen Islands. This machine, also manufactured by DAF INDAL, is shown in Figs. 19 and 20. The turbine has a two-bladed rotor 37 m long and 24 m in diameter. The blades are NACA 0018 air-foils with a 0.61-m chord and are made of extruded aluminum. Two horizontal struts, located at 20% of the rotor height from the ends, are used for structural rigidity and damping of the vibrations. The blades and struts are attached to a 1.5-m diameter tubular column made of aluminum, except for the two end cones which are of galvanized steel. For additional protection, the rotor is equipped with aerodynamic brakes located at the equator position of each blade. These brakes are held in the closed position by an electromagnetic latch which is released either by a centrifugal switch or by a signal from the control system.

The entire rotor assembly is supported by a bottom bearing, which rests on the top of a 9-m steel tower, and is held in position by four guy wires attached to the top bearing. The bottom bearing and coupling assembly is designed to allow for rotor tilt.

The mechanical drive train and generator are enclosed at the top of the base tower. The principal components are a hydraulically actuated disc brake, a 15.73:1 double-reduction gearbox, V-belts and pulleys. The pulleys were selected to provide a means of changing the turbine rotor speed while keeping the same generator speed.

The principal components of the electrical power system are illustrated in Fig.20. The generator, a 230-kW, 720-rpm, 600-V AC, 60-Hz, 3-phase delta, induction machine, is used as a motor to bring the turbine (non self-starting) up to almost synchronous speed. An autotransformer, or starter, is switched into the power circuit during starting in order to reduce the voltage. A 125-kvar capacitor bank is installed in the power line to compensate for the reactive power generated by the generator. Finally, a 300-kVA transformer steps the voltage up to 13.2 kV for the local grid.

The wind turine is equipped with a control system designed to provide fully automatic operation and protection. It is essentially a logic circuit which, with selected input signals, causes the turbine to start or stop. For example, signals from sensors indicating loss of line voltage, guy cable vibrations, generator overcurrent or excessive wind speeds will cause the main circuit breaker to open and the mechanical brake to be actuated. Malfunctions such as vibrations or overcurrent result in a stop that requires manual reset of the control system before the turbine can be restarted. The starting sequence is initiated after logic checks for adequate mean wind speeds, line voltage, etc.

Evaluation of the wind turbine involved measuring meteorological, mechanical and electrical parameters (48 channels). A mini-computer was used for recording and reducing the test data. Figure 21, by way of example, presents the performance characteristics of the wind turbine.

The test program was completed at the end of 1982 whereupon the wind turbine was handed over to the local authorities for use as an electric generating unit. It is now envisaged to install a farm of six wind turbines of this type for 1985.

2.2.4 Project Eole

Project Eole is a cooperative, cost-shared undertaking by Hydro-Quebec and the National Research Council Canada to design, build and evaluate a prototype multimegawatt-scale Darrieus wind turbine. This project is the child of the Magdalen Islands experiment and feasibility and economic studies on large-scale wind turbines. The project is managed by Hydro-Quebec while the design of the wind turbine system is carried out by Shawinigan Consultants Inc., a division of Lavalin. The project cost has been established at 35 million Canadian dollars. According to the schedule shown in Fig. 22, the wind turbine prototype will be commissioned in the fall of 1985.

Figure 23 shows the main components of the Eole wind turbine: the rotor equipped with aerobrakes, top and bottom bearings, guy wires, a disc brake, a generator directly coupled to the rotor, a frequency converter and the line voltage transformer; the control system is not shown in this figure. The general arrangement and dimensions of the wind turbine are presented in Fig. 25. The wind turbine has a two-bladed rotor 96 m high by 64 m in diameter. The blades are NACA 0018 airfoils of 2.4-m chord and will be made of steel, the various blade sections will be bolted. The blades are attached to a tubular steel column 5 m in diameter and stiffened by two struts located at 20% of the rotor height. As shown in Figure 23, the rotor will be equipped with aerobrakes (spoilers) located at the equator. The rotor is supported by a bottom bearing mounted on a concrete base 8.5 m high and is held vertical by means of six guy wires attached to the top bearing.

A pivot mounted on the bottom bearing allows for rotor tilt. A summary of the Eole characteristics is given in Fig. 24. The drive train is very simple, the generator being directly coupled to the rotor. As illustrated in greater detail in Fig. 26, it consists essentially of shaft segments, a pivot, a bottom bearing, a mechanical disc brake and flexible couplings. The generator is a low-frequency (14.5 rpm) synchronous AC machine installed on the floor inside the concrete base.

Figure 27 shows a diagram of the electric power system. The most innovative component is definitely the static frequency converter that links the wind turbine generator to the grid. The converter, an AC-DC-AC system comprising microprocessor-controlled thyristors, allows the generator, and consequently the wind turbine rotor, to operate at variable speed while maintaining the electrical current injected into the grid at constant voltage and frequency.

It will be also used for starting and braking the wind turbine, the final stopping sequence of the machine being done by the mechanical brake. In the cases of malfunction of the converter or a power grid failure, a bank of resistors will be connected to the electrical generator. Finally, if all these systems fail, the aerobrakes will be deployed automatically to prevent the machine overspeeding.

The wind turbine will be equipped with a control system designed to provide fully automatic operation and protection. A microprocessor will perform these tasks.

Since Eole is the first prototype of a large Darrieus wind turbine, the machine will be fully instrumented for evaluating its performance and the complete system behavior. Over 500 parameters will be monitored and measured using a minicomputer for recording and reducing the test data.

Questions and Answers

Q. I have one question, Albert. In one of the early graphs you showed two curves of wind versus time. One of the curves was measured windspeed, a daily average or something, and the other curve was the predicted? If so, how far ahead was the prediction made?

A. Yes, it is a prediction of the wind speed. Knowing the wind speed values for the previous hours, the model permits the prediction of what the wind speed value will be for the next hour.

Q. But only for one hour.

A. One hour, one hour in advance.

Q. What's the basis of that prediction? A fraction of the previous wind or what? What goes into the atmospheric physics?

A. I cannot answer your question. You can find a reference to the forecast method in the CEA report #222 G341.

Q. Maybe I could comment on the previous question on how the predications were done. I've seen the report by Lars Jenkins. They use time series correlations. So you are doing a curve 'A' with a series of data that will produce the best coefficients for predicting windspeeds. My question for Albert: Can you explain the relationship of IREQ with Hydro Quebec? Are you an independent, semi-independent body or ...?

A. No, we are the same company. We are a division of Hydro Quebec. We used to have special status at the beginning, ten years ago, but now we are fully integrated. We have a Vice-President in Hydro-Quebec.

Q. So your interest in wind power is Hydro Quebec's interest in wind power?

A. Exactly. It's why everything now is revised because the interest has changed.

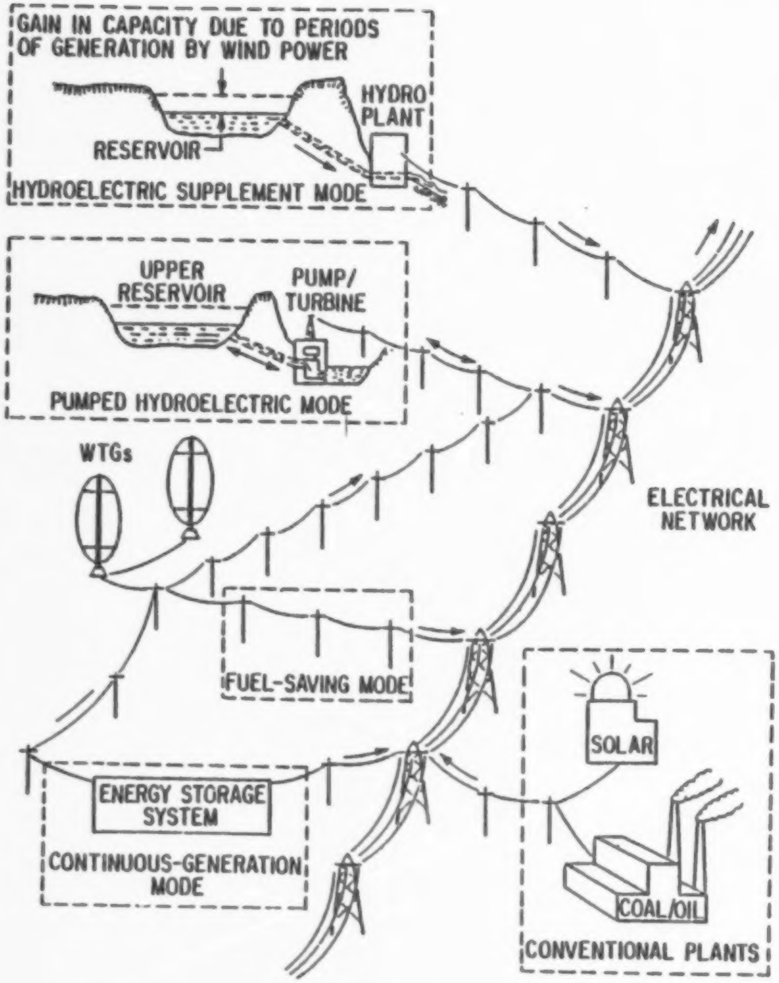

GAIN IN CAPACITY DUE TO PERIODS OF GENERATION BY WIND POWER
HYDRO PLANT
RESERVOIR
HYDROELECTRIC SUPPLEMENT MODE
UPPER RESERVOIR
PUMP/ TURBINE
PUMPED HYDROELECTRIC MODE
WTGs
ELECTRICAL NETWORK
FUEL-SAVING MODE
SOLAR
ENERGY STORAGE SYSTEM
CONTINUOUS-GENERATION MODE
COAL/OIL
CONVENTIONAL PLANTS

Fig. 1 : Utilization Schemes for WECS

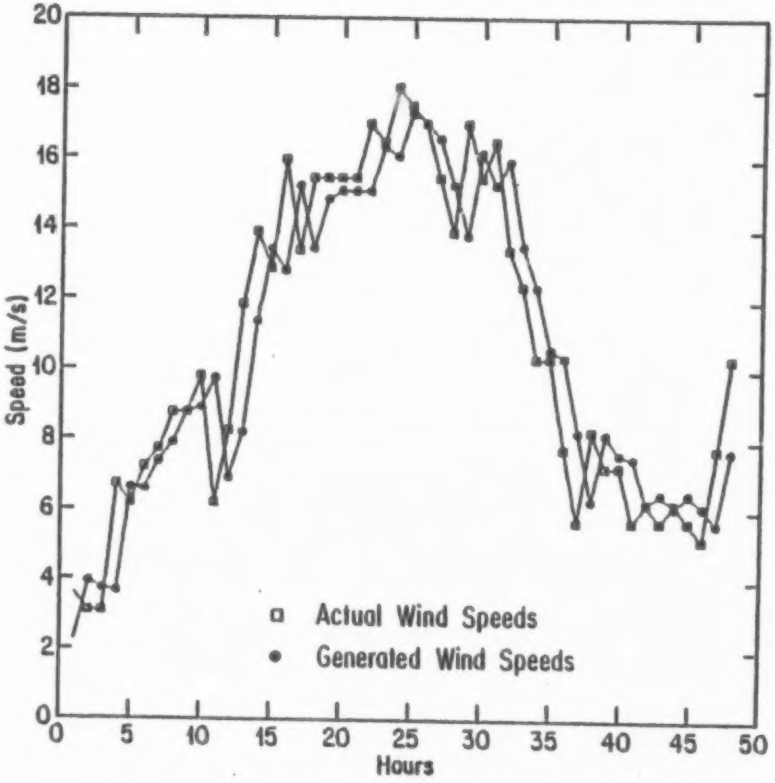


Fig. 2 : Wind Forecasting

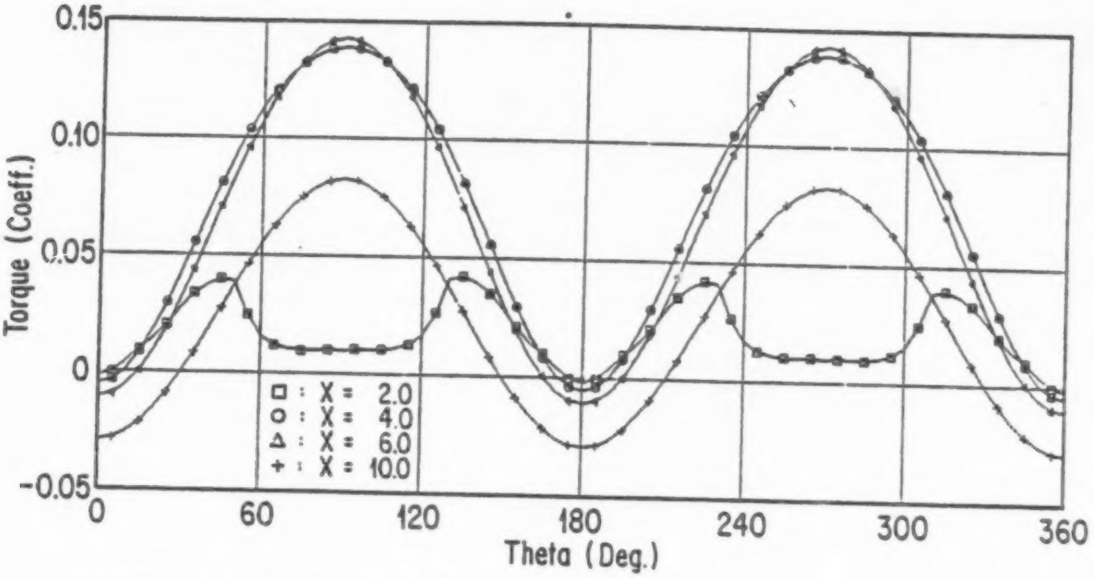


Fig. 3 : Aerodynamic Torque versus Azimuth Angle for Various Tip Speed Ratios

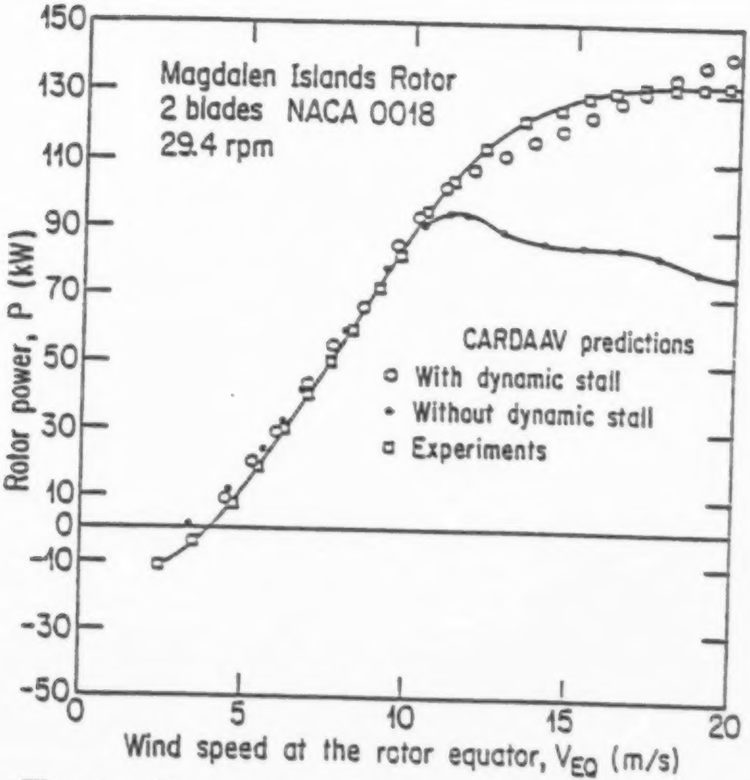


Fig. 4 : Comparison between Theoretical and Experimental Aerodynamic Performance Data

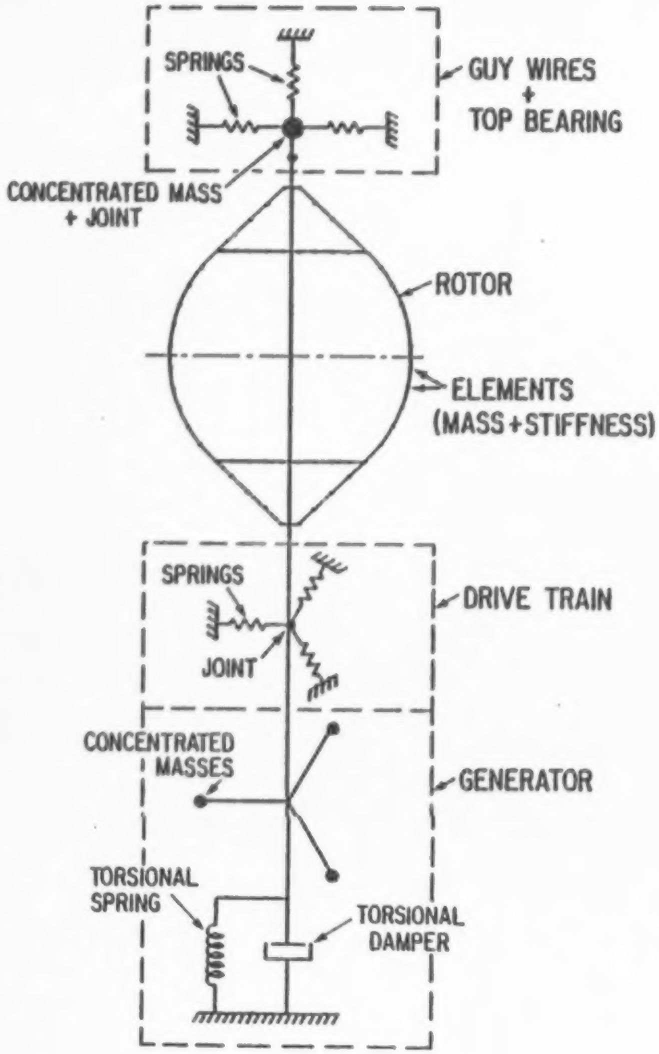

SPRINGS
GUY WIRES + TOP BEARING
CONCENTRATED MASS + JOINT
ROTOR
ELEMENTS (MASS + STIFFNESS)
SPRINGS
DRIVE TRAIN
JOINT
CONCENTRATED MASSES
GENERATOR
TORSIONAL SPRING
TORSIONAL DAMPER

Fig. 5 : Modeling of a Wind Turbine Rotor

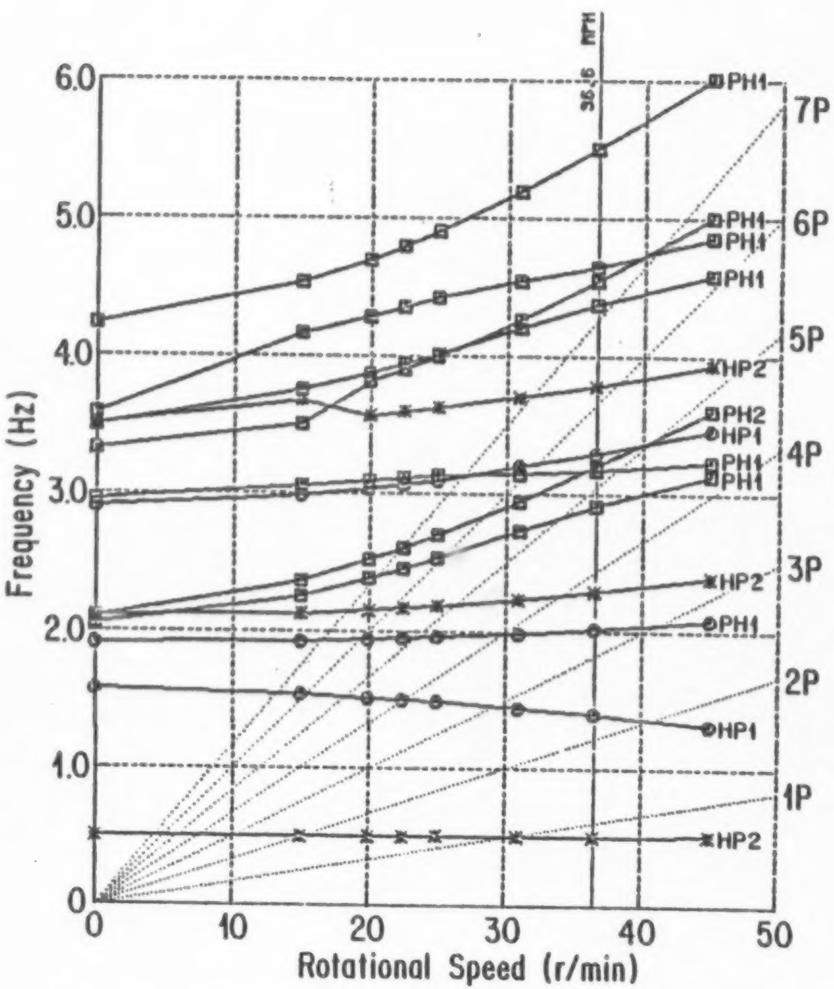
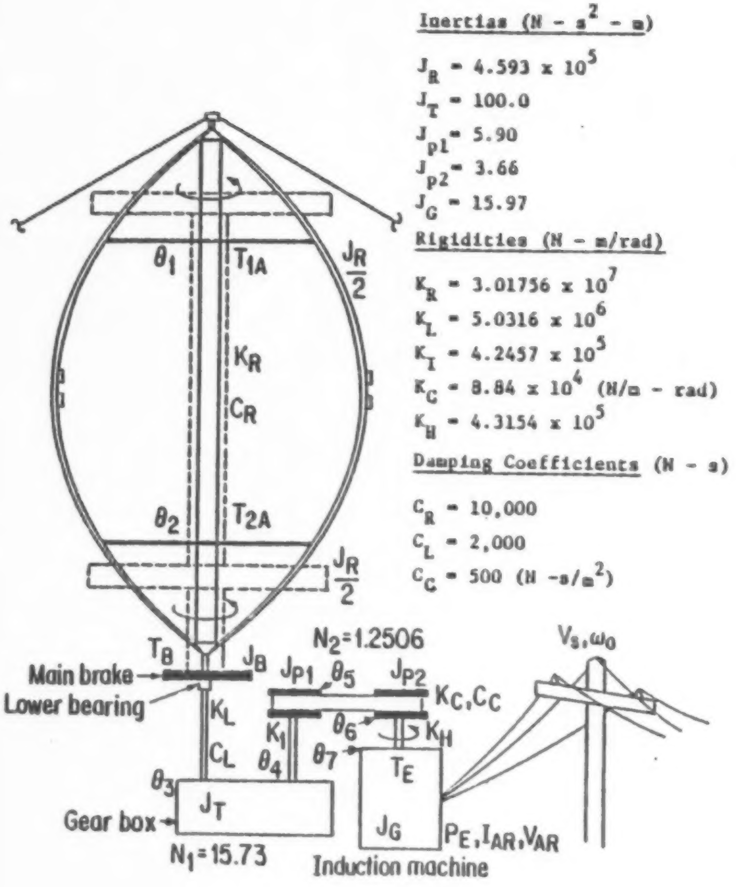


Fig. 6 : Vibration Modes of the Magdalen Islands Wind Turbine


θ_1
T_{1A}
$\frac{J_R}{2}$
K_R
C_R
θ_2
T_{2A}
$\frac{J_R}{2}$
T_B
J_B
Main brake
Lower bearing
K_L
C_L
θ_3
Gear box
J_T
$N_1=15.73$
$N_2=1.2506$
J_{P1}
θ_5
J_{P2}
K_C, C_C
K_1
θ_4
θ_6
θ_7
K_H
T_E
J_G
P_E, I_{AR}, V_{AR}
Induction machine
V_s, ω_0

Inertias ($N - s^2 - m$)

$J_R = 4.593 \times 10^5$
$J_T = 100.0$
$J_{p1} = 5.90$
$J_{p2} = 3.66$
$J_G = 15.97$

Rigidities ($N - m/rad$)

$K_R = 3.01756 \times 10^7$
$K_L = 5.0316 \times 10^6$
$K_I = 4.2457 \times 10^5$
$K_C = 8.84 \times 10^4$ ($N/m - rad$)
$K_H = 4.3154 \times 10^5$

Damping Coefficients ($N - s$)

$C_R = 10{,}000$
$C_L = 2{,}000$
$C_C = 500$ ($N - s/m^2$)

Fig. 7 : Simulation of the Magdalen Islands Wind Turbine

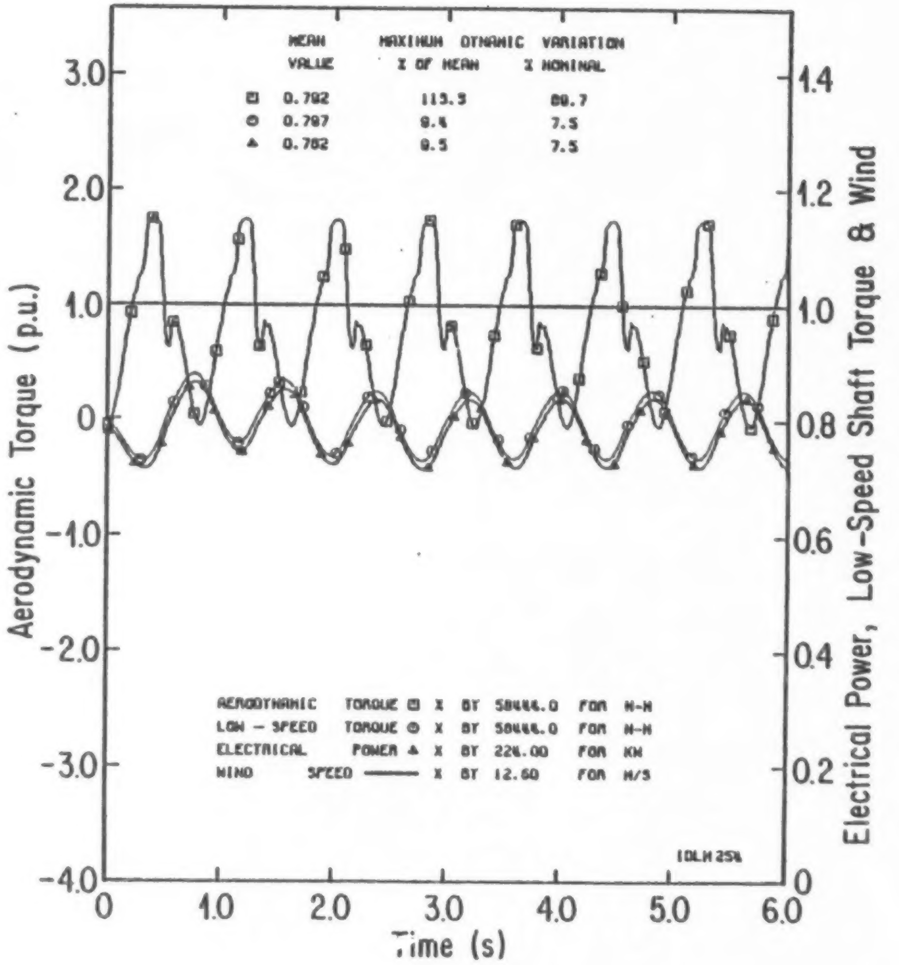


Fig. 8 : Normal Operation

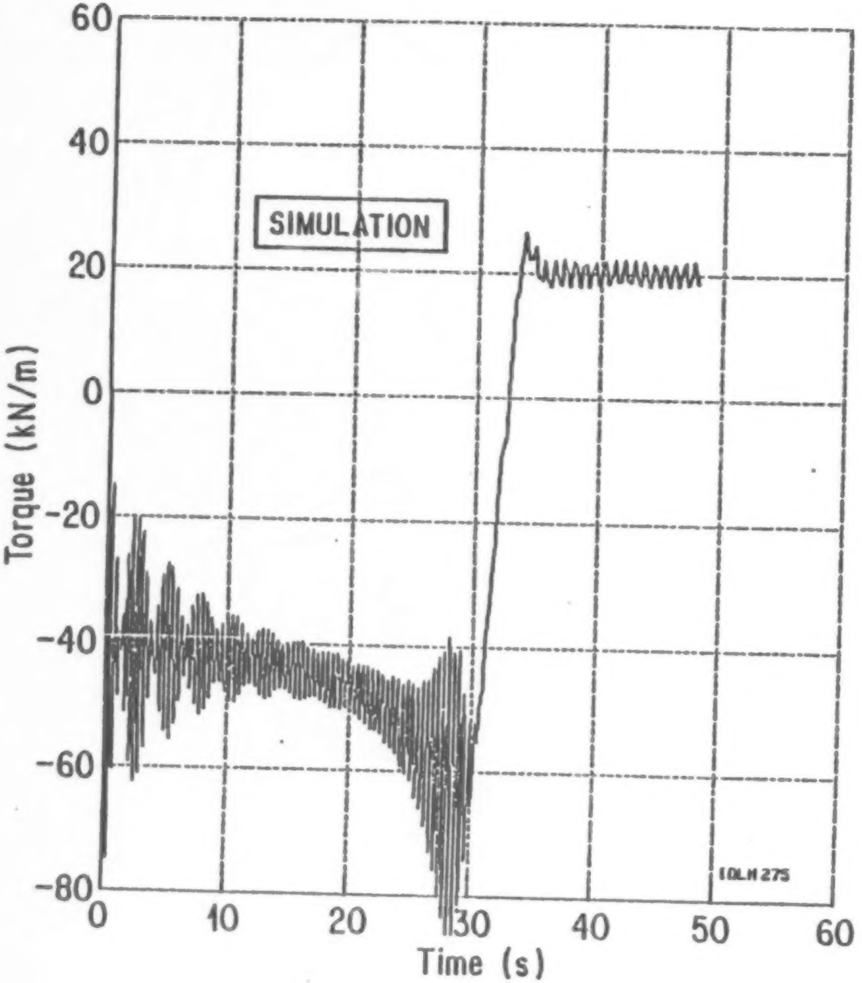


Fig. 9 : Low-Speed Shaft Torque
Magdalen Islands Wind Turbine
Starting Sequence

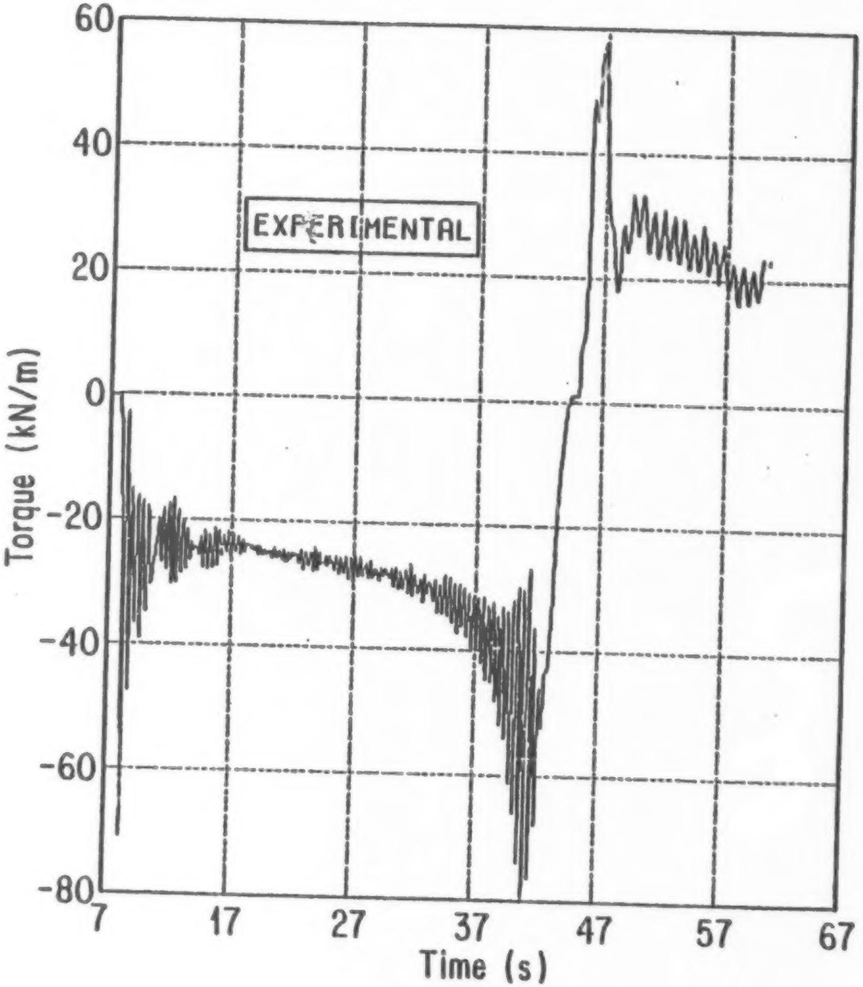


Fig. 10 : Low-Speed Shaft Torque
Magdalen Islands Wind Turbine
Starting Sequence

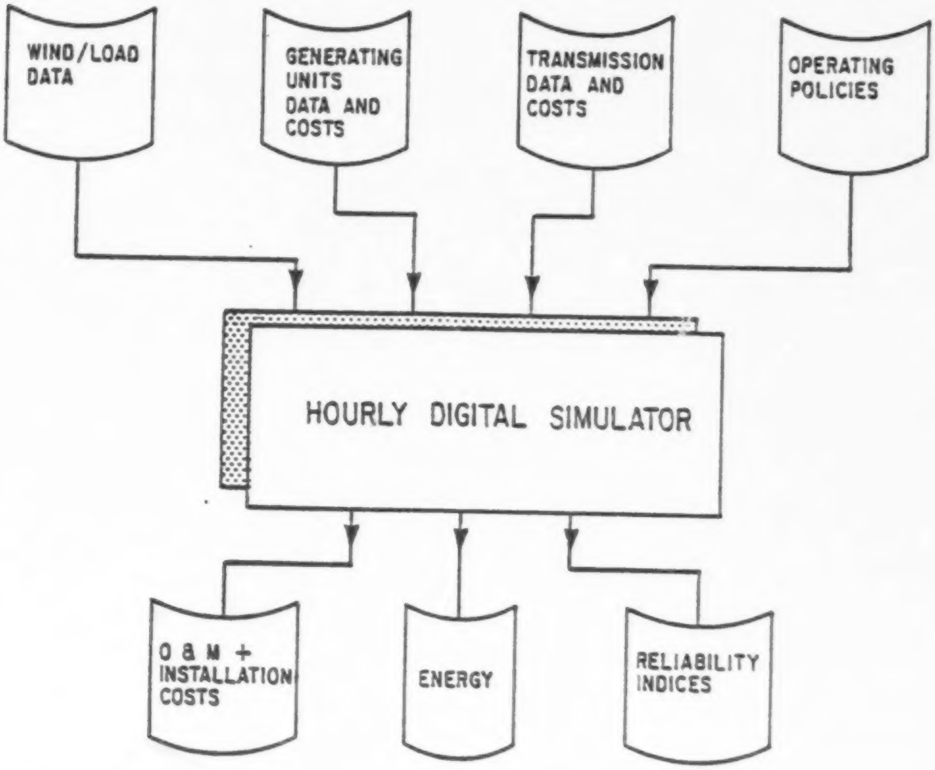

WIND/LOAD DATA
GENERATING UNITS DATA AND COSTS
TRANSMISSION DATA AND COSTS
OPERATING POLICIES
HOURLY DIGITAL SIMULATOR
O & M + INSTALLATION COSTS
ENERGY
RELIABILITY INDICES

Fig. 11 : Digital Simulator-Summary

GENERATING UNITS DATA & COSTS

- GENERATING CAPACITY
- WIND/POWER CURVE (WIND TURBINES)
- MINIMUM LOADING (CONVENTIONAL UNITS)
- START-UP TIME (CONVENTIONAL UNITS)
- COMMITMENT PRIORITY
- FUEL COST (CONVENTIONAL UNITS)
- MUST-RUN UNITS (CONVENTIONAL UNITS)
- ENERGY LIMITATION (HYDRO)
- MAINTENANCE POLICY & COSTS
- FAILURE RATE
- MEAN REPAIR TIME
- REPAIR COSTS

WIND/LOAD DATA

- PARAMETERS OF THE WIND AND LOAD MODELS
- PROPORTION OF THE LOAD AT EACH NODE
- SCALING FACTORS FOR THE LOAD AND THE WIND

TRANSMISSION DATA & COSTS

- FAILURE RATE
- MEAN REPAIR TIME
- REPAIR COSTS

OPERATING POLICIES

- SPINNING-RESERVE POLICY & CRITERIA
- COMMITMENT POLICY (PRIORITY AND PRODUCTION COST AT NOMINAL LOAD)

Fig. 12 : Digital Simulator Main Input

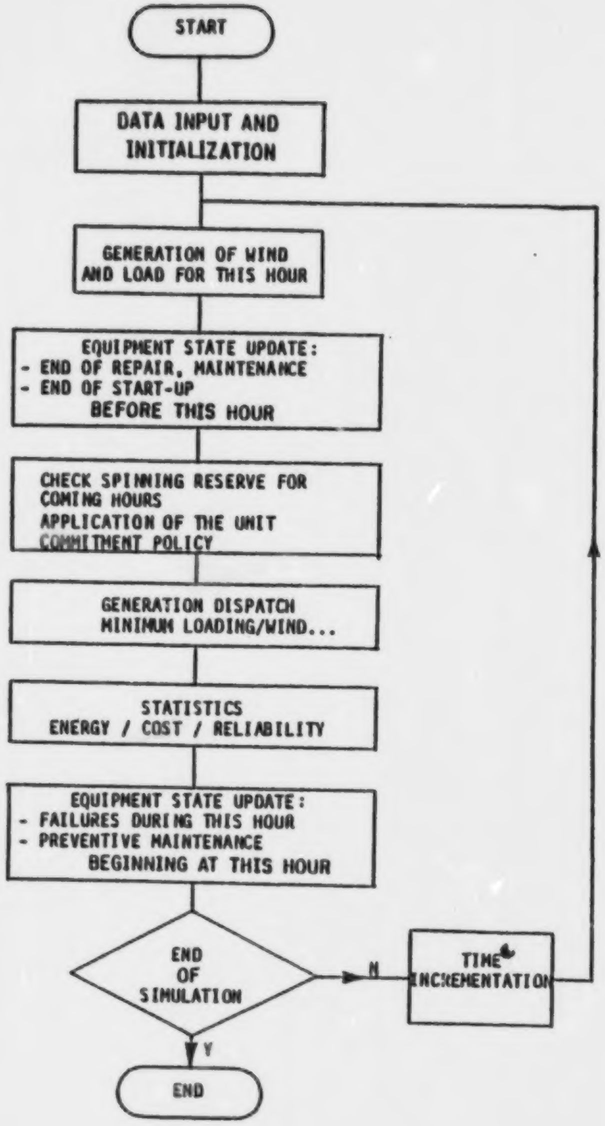
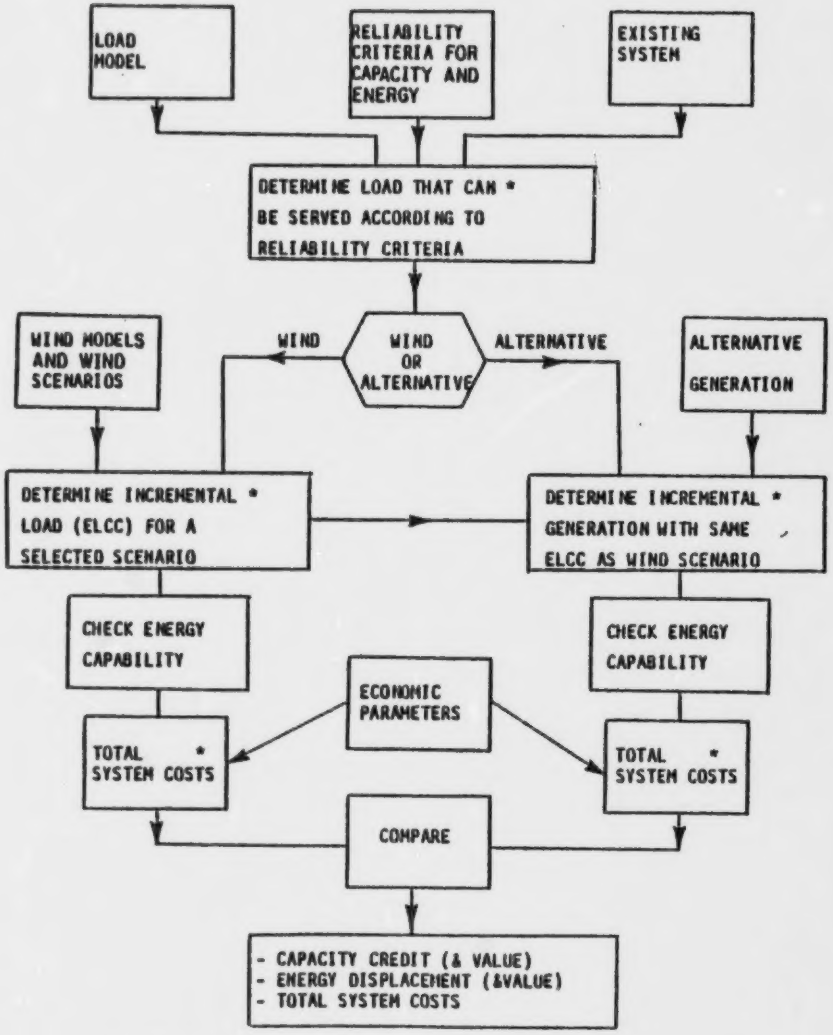

START
DATA INPUT AND INITIALIZATION
GENERATION OF WIND AND LOAD FOR THIS HOUR
EQUIPMENT STATE UPDATE:
- END OF REPAIR, MAINTENANCE
- END OF START-UP
BEFORE THIS HOUR
CHECK SPINNING RESERVE FOR COMING HOURS
APPLICATION OF THE UNIT COMMITMENT POLICY
GENERATION DISPATCH
MINIMUM LOADING/WIND...
STATISTICS
ENERGY / COST / RELIABILITY
EQUIPMENT STATE UPDATE:
- FAILURES DURING THIS HOUR
- PREVENTIVE MAINTENANCE
BEGINNING AT THIS HOUR
END OF SIMULATION
N
Y
TIME INCREMENTATION
END

Fig. 13 : Hour by Hour Simulation


LOAD MODEL
RELIABILITY CRITERIA FOR CAPACITY AND ENERGY
EXISTING SYSTEM
DETERMINE LOAD THAT CAN * BE SERVED ACCORDING TO RELIABILITY CRITERIA
WIND OR ALTERNATIVE
WIND
ALTERNATIVE
WIND MODELS AND WIND SCENARIOS
ALTERNATIVE GENERATION
DETERMINE INCREMENTAL * LOAD (ELCC) FOR A SELECTED SCENARIO
DETERMINE INCREMENTAL * GENERATION WITH SAME ELCC AS WIND SCENARIO
CHECK ENERGY CAPABILITY
CHECK ENERGY CAPABILITY
ECONOMIC PARAMETERS
TOTAL * SYSTEM COSTS
TOTAL * SYSTEM COSTS
COMPARE
- CAPACITY CREDIT (& VALUE)
- ENERGY DISPLACEMENT (&VALUE)
- TOTAL SYSTEM COSTS

* OBTAINED FROM SIMULATIONS

Fig. 14 : Economic Analysis Methodology for One Year

ENERGY

- ENERGY PRODUCED BY EACH UNIT
- FUEL CONSUMPTION BY EACH UNIT
- WIND ENERGY NOT ABSORBED
- TOTAL SYSTEM LOAD

RELIABILITY

- ENERGY NOT SERVED
- FREQUENCY AND DURATION OF LOAD CURTAILMENTS

COSTS

- FUEL AND OPERATING COSTS
- PREVENTIVE-MAINTENANCE COSTS
- REPAIR COSTS
- INSTALLATION COSTS FOR NEW UNITS
- COST PER KWH FOR NEW UNITS

Fig. 15 : Simulator Main Output

Fig. 16 : 40-kW Wind Turbine

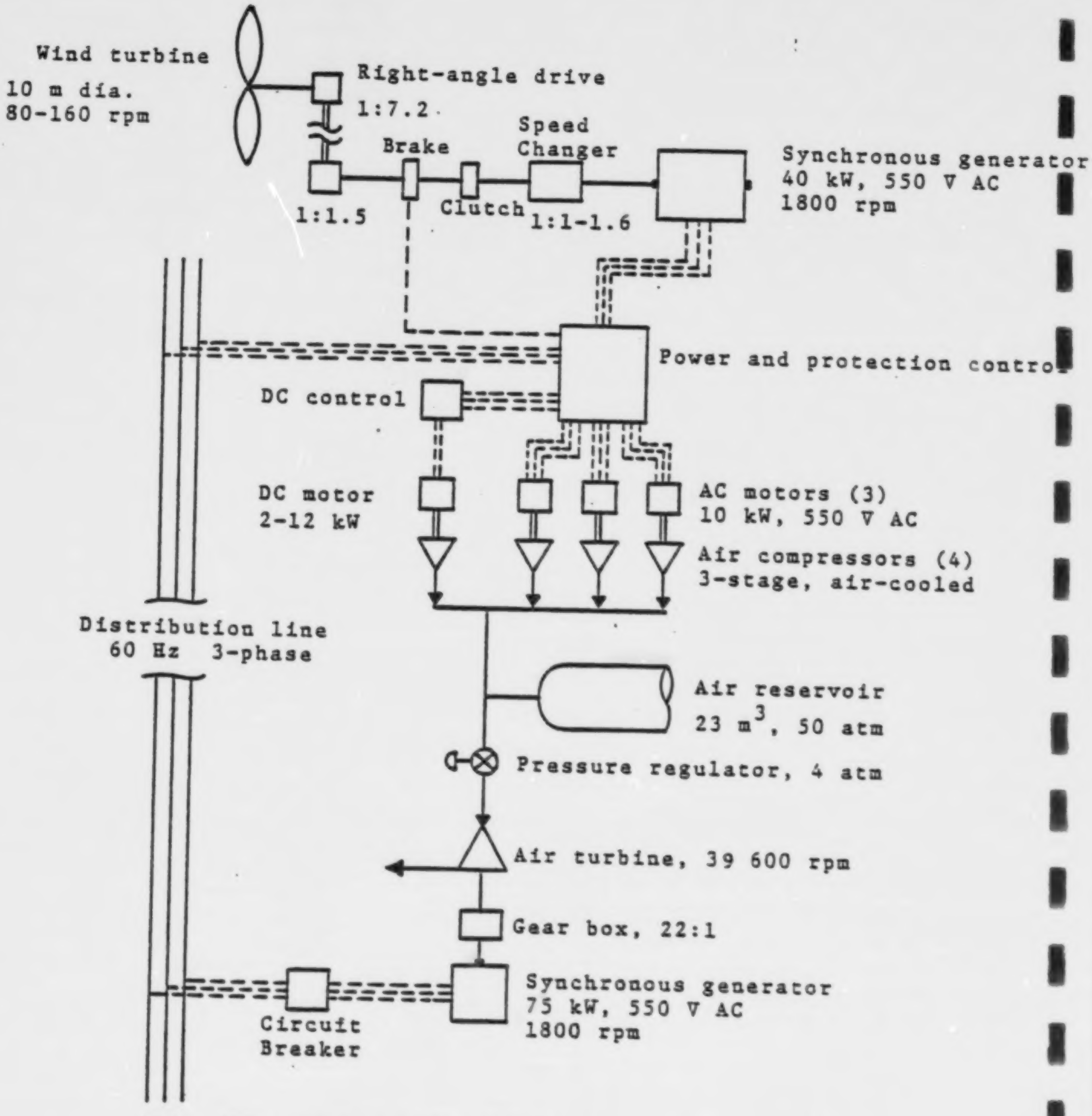

Wind turbine
10 m dia.
80-160 rpm
Right-angle drive
1:7.2
1:1.5
Brake
Clutch
Speed Changer
1:1-1.6
Synchronous generator
40 kW, 550 V AC
1800 rpm
Power and protection contro
DC control
DC motor
2-12 kW
AC motors (3)
10 kW, 550 V AC
Air compressors (4)
3-stage, air-cooled
Distribution line
60 Hz 3-phase
Air reservoir
23 m³, 50 atm
Pressure regulator, 4 atm
Air turbine, 39 600 rpm
Gear box, 22:1
Synchronous generator
75 kW, 550 V AC
1800 rpm
Circuit Breaker

Fig. 17 : IREQ Wind Energy Conversion and Storage Systems

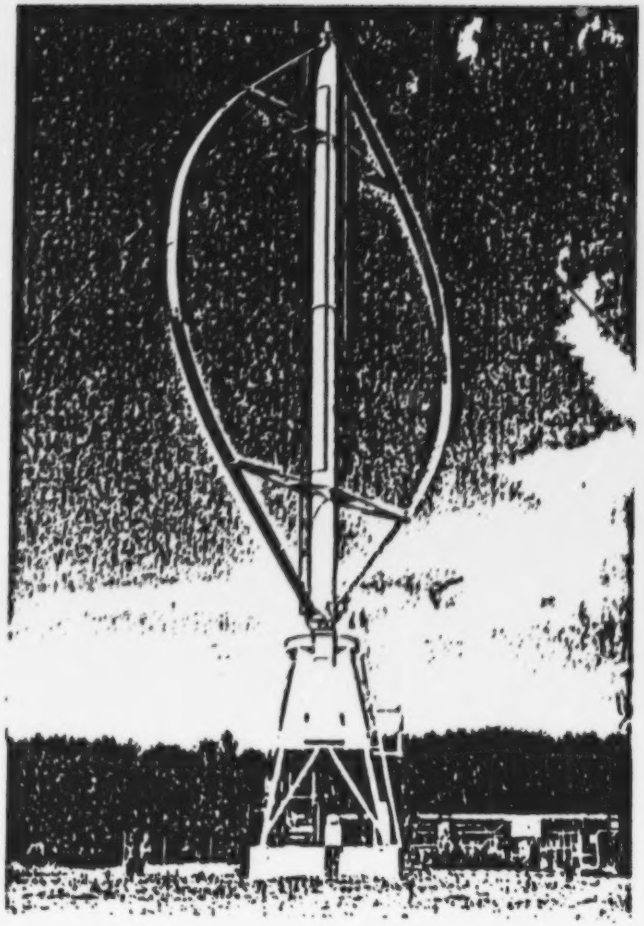


Fig.18 : 50-kV Wind Turbine

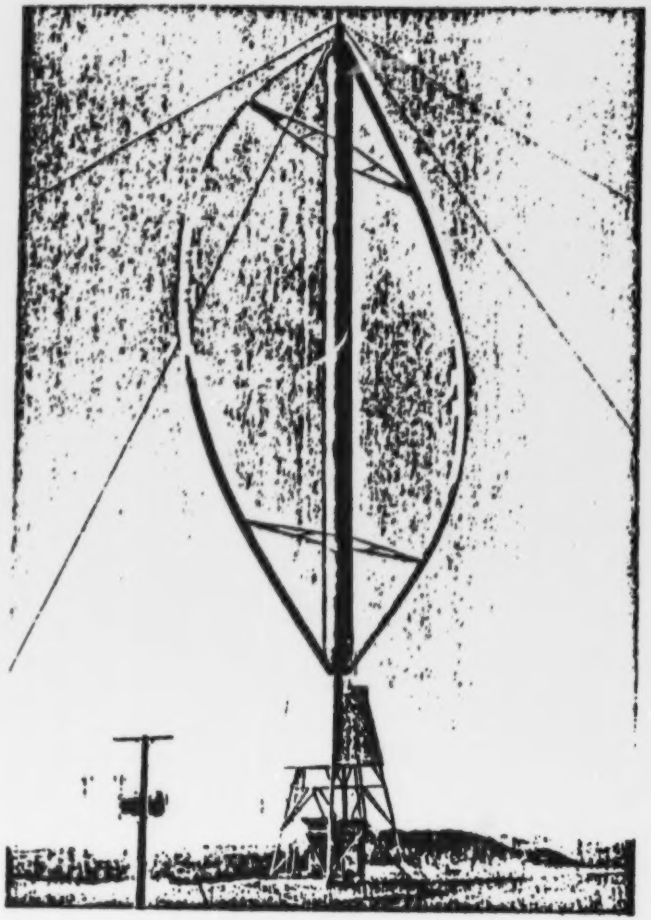


Fig.19 : Magdalen Islands
230-kV Wind Turbine

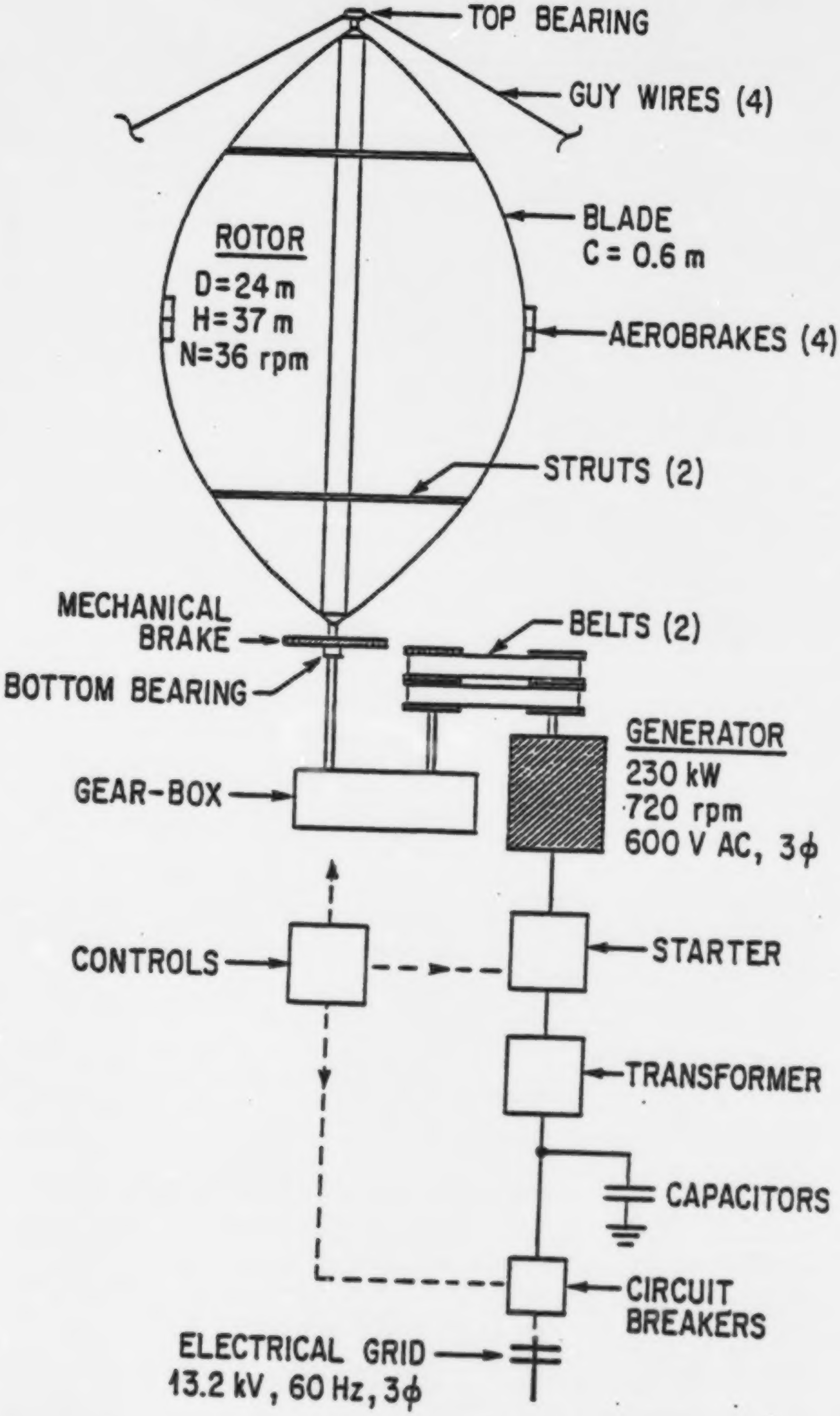

TOP BEARING
GUY WIRES (4)
BLADE
C = 0.6 m
ROTOR
D=24 m
H=37 m
N=36 rpm
AEROBRAKES (4)
STRUTS (2)
MECHANICAL BRAKE
BOTTOM BEARING
BELTS (2)
GENERATOR
230 kW
720 rpm
600 V AC, 3ϕ
GEAR-BOX
CONTROLS
STARTER
TRANSFORMER
CAPACITORS
CIRCUIT BREAKERS
ELECTRICAL GRID
13.2 kV, 60 Hz, 3ϕ

Fig. 20: Schematic of the Magdalen Islands Wind Turbine

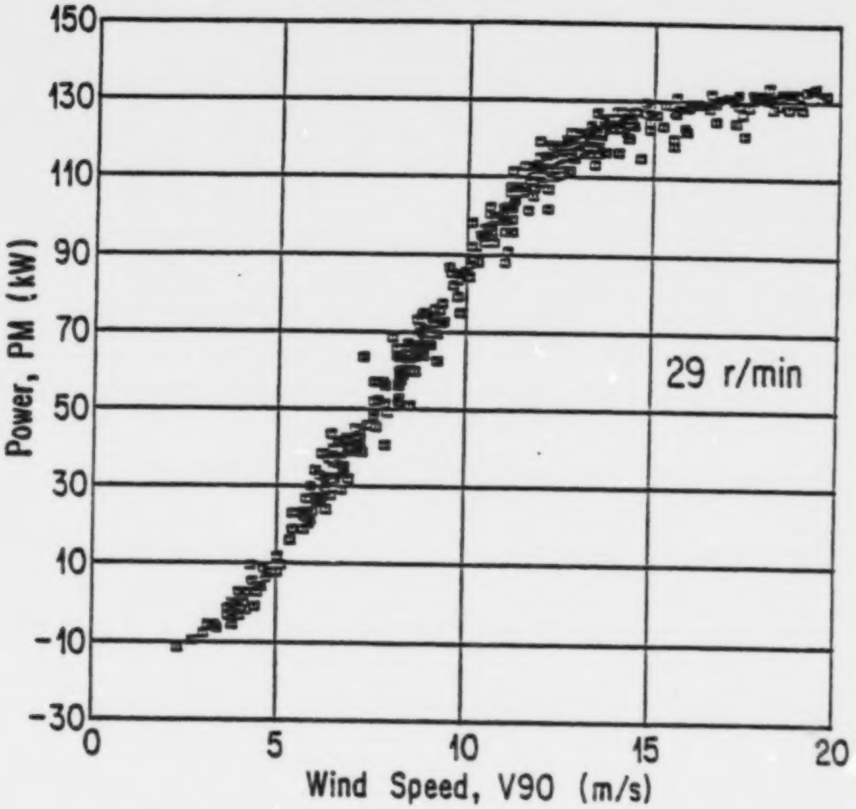


Fig. 21 : Magdalen Islands Wind Turbine Performance

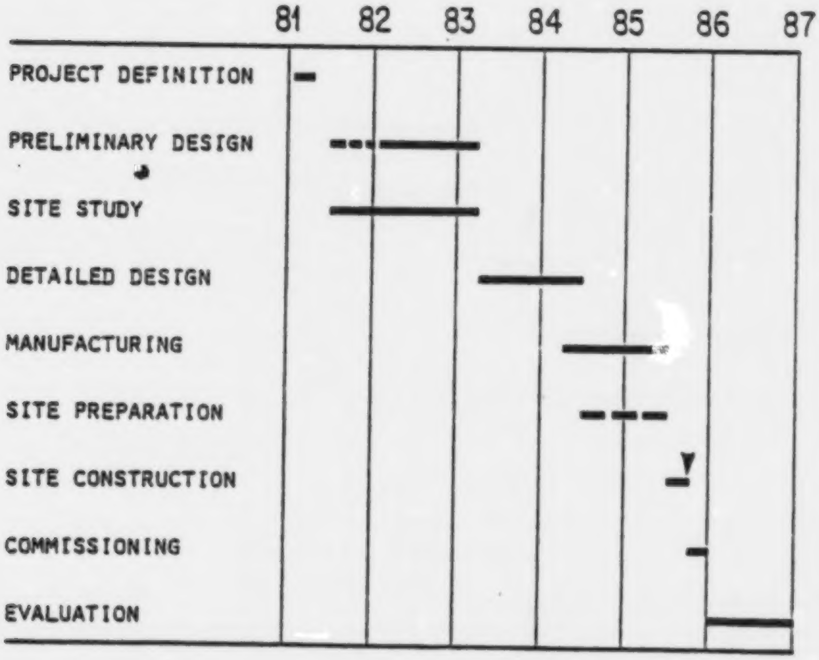


Fig. 22 : Project Éole Schedule

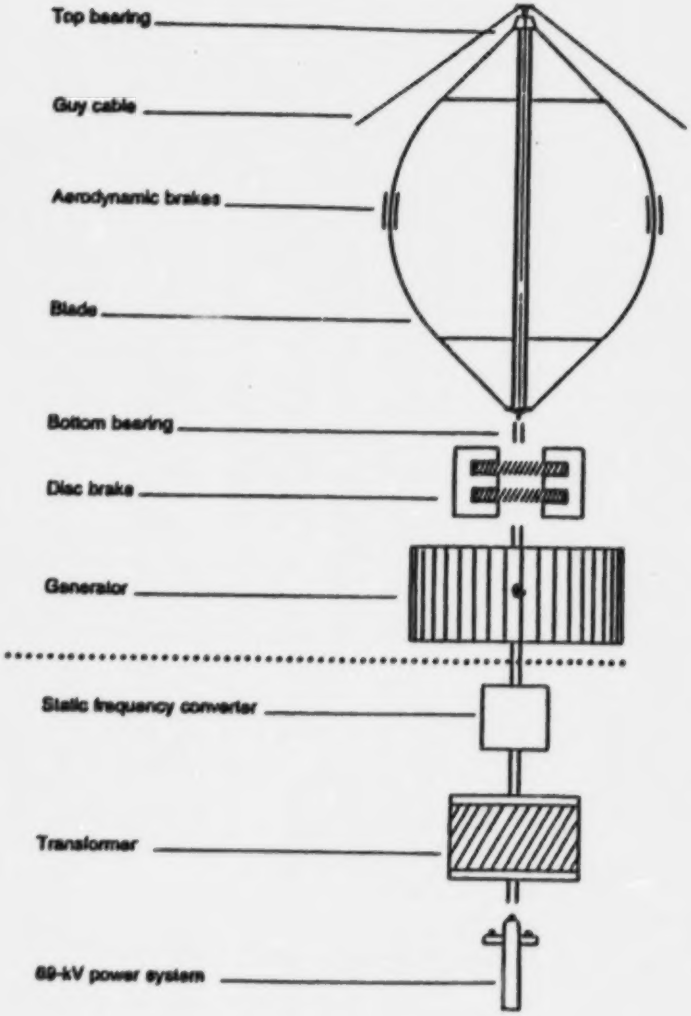
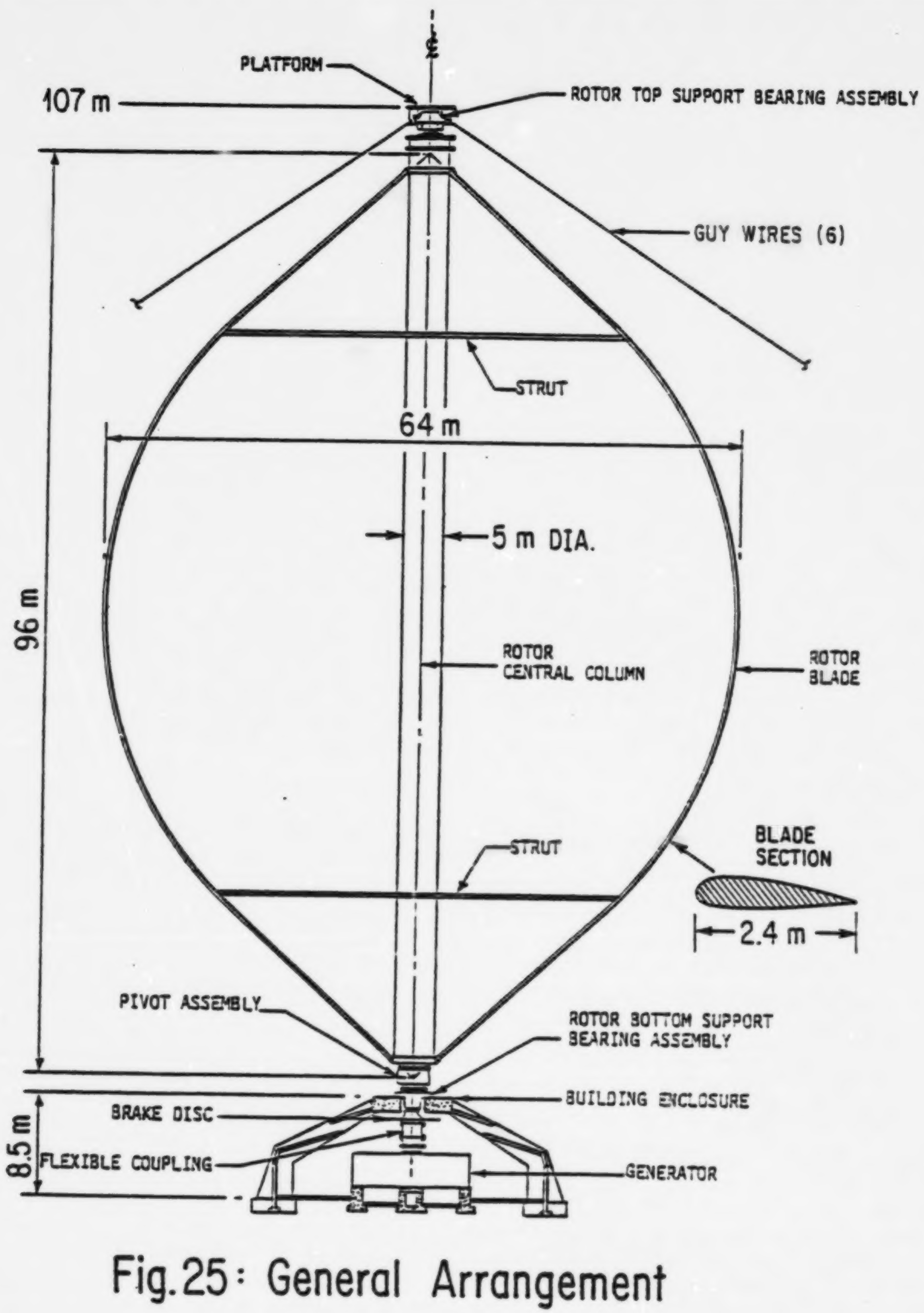

Top bearing
Guy cable
Aerodynamic brakes
Blade
Bottom bearing
Disc brake
Generator
Static frequency converter
Transformer
69-kV power system

Fig.23 : Éole Components

ROTOR SWEPT AREA	: 4000 M^2
ROTOR HEIGHT	: 96 M
ROTOR DIAMETER	: 64 M
TOTAL HEIGHT	: 107 M
NUMBER OF BLADES	: 2
BLADE CHORD	: 2.4 M
GUY WIRES	: 6, AT 35^0
NOMINAL RATING	: 4 MW
NOMINAL ROTATIONAL SPEED	: 14.5 RPM
NOMINAL WIND SPEED	: 20 M/S (EQUATOR)
CUT-OUT WIND SPEED	: 26 M/S (EQUATOR)
ROTOR MAXIMUM SPEED	: 19 RPM

Fig. 24 : Éole Characteristics



PLATFORM
107 m
ROTOR TOP SUPPORT BEARING ASSEMBLY
GUY WIRES (6)
STRUT
64 m
5 m DIA.
96 m
ROTOR CENTRAL COLUMN
ROTOR BLADE
STRUT
BLADE SECTION
2.4 m
PIVOT ASSEMBLY
ROTOR BOTTOM SUPPORT BEARING ASSEMBLY
BUILDING ENCLOSURE
BRAKE DISC
8.5 m
FLEXIBLE COUPLING
GENERATOR

Fig. 25: General Arrangement

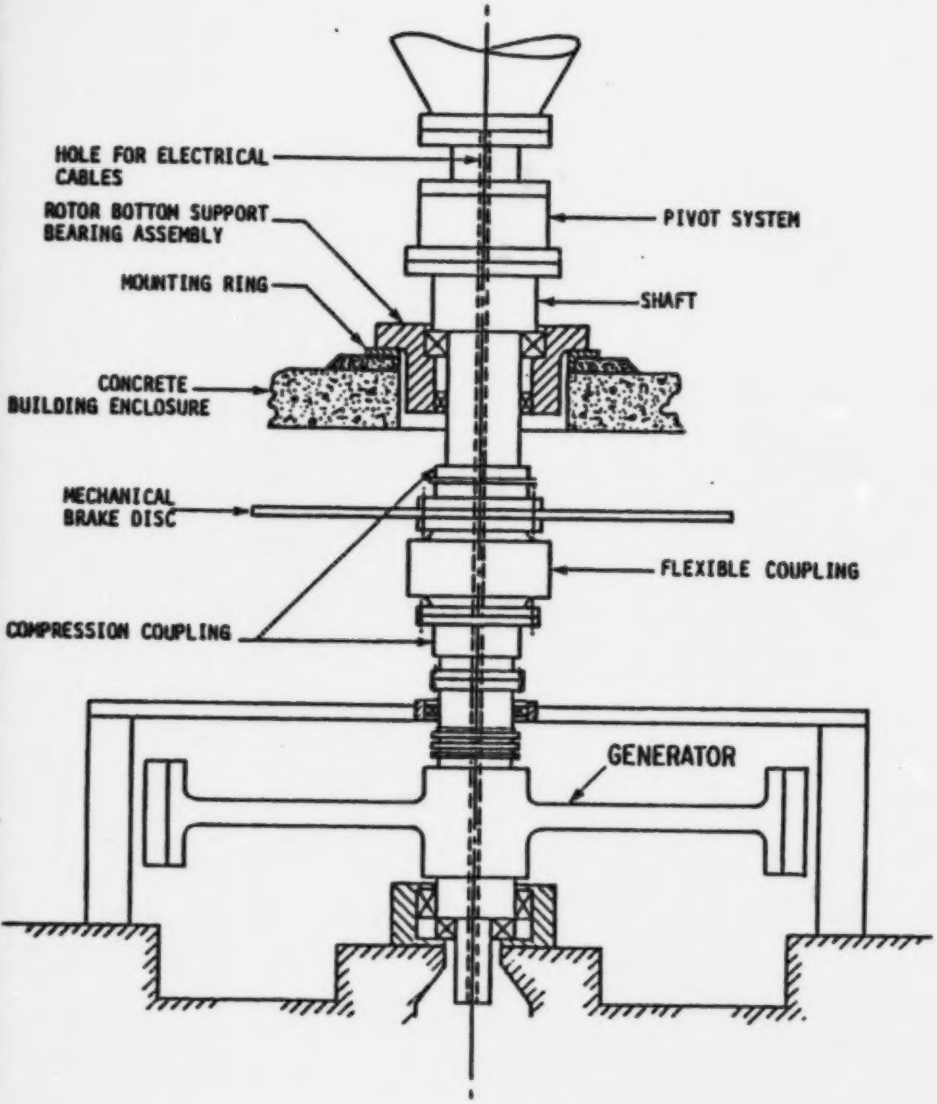

HOLE FOR ELECTRICAL CABLES
ROTOR BOTTOM SUPPORT BEARING ASSEMBLY
MOUNTING RING
CONCRETE BUILDING ENCLOSURE
MECHANICAL BRAKE DISC
COMPRESSION COUPLING
PIVOT SYSTEM
SHAFT
FLEXIBLE COUPLING
GENERATOR

Fig. 26: Power Train Configuration

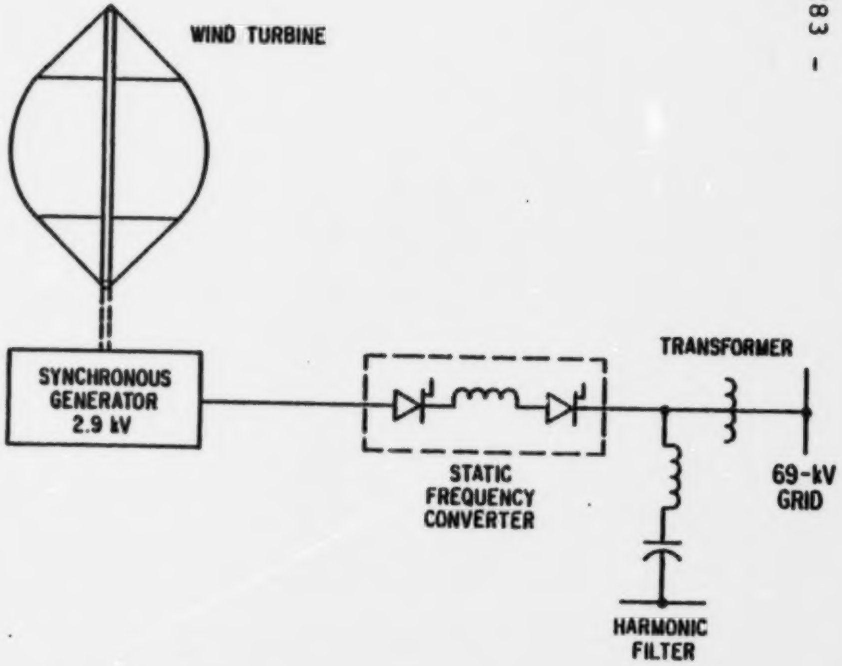

WIND TURBINE
SYNCHRONOUS GENERATOR 2.9 kV
STATIC FREQUENCY CONVERTER
TRANSFORMER
HARMONIC FILTER
69-kV GRID

Fig. 27: Schematic of Wind Turbine System

PROJET ÉOLE

Berge Tahmazian, Hydro-Québec

Ladies and Gentlemen. I will be speaking today about:

- the progress of Projet Eole,
- the cost
- the calendar
- the technical content

and - the work progress of the project.

Eole is a research and development project.

The objectives of the project are to design, build and evaluate a 4 megawatt, grid-connected prototype and to develop a Canadian market.

The success of the future machine is based on the premise that the cost is competitive.

The National Research Council of Canada and the Institut de Recherche d'Hydro-Québec are the promoters of the project. It is managed by Hydro-Québec. Shawinigan/Lavalin are the consulting engineers.

The cost of the project was established at $35.2 million and still is $35.2 million.

SCHEDULE

Projet Eole will be commissioned in the fall of 1985 and there will be a one year evaluation programme afterwards (Fig. 2).

Preliminary design was completed in early 1983.

The engineering at this stage is very advanced. Last September we had a very positive 'critical design review'. After this review we had to relax some of the design requirements, like the cut-out speed, and make other small changes, like adding a damper or other minor modifications.

The site work, the civil work, is very advanced. Ninety per cent of the contracts are already awarded.

We think that we will respect the schedule and the machine will be commissioned in the Fall of 1985.

COSTS

Figure 3 shows the distribution of the costs in the years 1981, '82, '83 and '84. Notice that we have already spent around $18 million.

Figure 4 also shows the cost distribution according to the different aspects of the project:

- For the permanent equipment, including installation, we have about $15 million,
- engineering $13 million,
- the site work, the civil work is $3 million,
- administration is $2 million

and - for the evaluation period around $1.5 million;

For a total of around $35 million.

For the permanent equipment, figure 5 shows the cost breakdown:

- the rotor is around $5 million, including installation,
- the electrical equipement is around $7 million, including installation,
- the drive train around $2 million,

and - for miscellaneous instrumentation, another one million dollar.

COMPONENTS

Eole will feature a direct drive synchronous generator, as shown on Fig. 8. You can see the different composents of the machine in Figures 6 and 7: the rotor top support beauring, six guy wires of a 3.5 inch diameter, the struts, the pivot assembly, the flexible coupling, the disc brake and the supporting building. The aerodynamic brakes are missing on the drawing.

THE CONTRACTS

There are three major areas for contracts. Details are shown on Figures 9, 14 and 17.

The rotor was awarded to Versatile Vickers in April 1984. The fabrication began in October 1984. The column is under fabrication at this moment and in a couple of weeks fabrication of the blades will begin. The beginning of the assembly on the site is May 1985. End of erection is scheduled for October 1985.

The guying system has not been awarded yet. It is expected to be delivered on site in May 1985.

The pivot, the brakes, the flexible coupling and the bearing, have been awarded to Hayes-Dana.

The installation of the drive train will probably be done by General Electric, but it is under negotiation at this moment.

The electrical and control system was also awarded to Canadian General Electric in April 1984. The final assembly will be completed in September 1985. The instrumentation contract is not yet awarded.

WORK PROGRESS

Figures 10 to 13 are photos of the rotor column taken at Versatile Vickers in Montréal. They show the reinforcement for the sections of the column. You can see different sections of the column. It's a five meter diameter column, 12 mm. thick, in sections approximatily 4 meters long. There are 22 sections. They will be assembled in the plant and transported in six different sections and bolted on site. Here you can see other sections of the column with the reinforcing plate in between sections.

Figure 15 and 16 are photos of the calipers of the brake, it's a one ton machine. There will be six of them on EOLE. It's from Hayes-Dana. The flexible coupling also from Hayes-Dana is specified for 10,000 kilonewton-meters.

These photos (figures 18 to 22) were taken in Montreal at General Electric, Dominion Engineering plant. They show parts of the generator. For transportation, the rotor and the stator will be in four sections assembled on the site.

EOLE SITE

The site chosen for EOLE is at Cap-Chat on the Gaspé peninsula, some 270 miles from Québec City. Eole will be located at half a mile from the river, on a plateau. Figures 23 and 24 show the location while Fig. 25 is an aerial view of the site area.

Figures 26 to 33 show the civil work on site, the building enclosure. The photos show the scaffolding, the spider legs, there bill be six of them, and the building proper. The pictures were taken in November and December. Around the end of December the whole building will be closed and only the inside will remain to be completed for the base of the generator.

Before finishing, I want to point out that, in spite of its complexity, this project has been made possible because we had a very close collaboration amongst the National Research Council, the researchers at IREQ, the consulting engineers and the manufacturers. Without a very close collaboration in this kind of project, it is very difficult to succeed: technically, on time, and on schedule.

I would like to thank Jacquelin Déry who helped me prepare all the slides and made this presentation possible.

Thank you.

Question and Answers

Q. Just a general question. After the project has been completed and successfully demonstrated without operating problems, say in 1986, is Hydro-Québec or IREQ going to market this particular unit or what are the future plans now that NRC is no longer a future supporter? That's the first question.

A. Okay. I will try to answer that. First of all, I want to insist that I am the project manager. The promoters, IREQ and the National Research Council, are the deciders. However, I have been involved in the project and I can try to answer your question. We can imagine a lot of scenarios as to what will happen after EOLE. The first thing is to get the financing. If we get the financing, I think that the second generation of EOLE would be much cheaper. We have already different optimized configurations that will make the whole project much cheaper. Probably, the building will not be a supporting building. The new configuration can be a direct drive down to the base of the generator. So it may be much cheaper. Afterwards, before it can be marketable, before you can really sell it, it probably has to go to a third generation. This is my personal opinion. But, the most important thing is to get the money and the answer is with the National Research Council and IREQ.

Q. What do you fell the cost projection will be for a commercial unit, which I guess nobody knows?

A. I can try to guess. Instead of, like, $15 million or $17 million for Projet EOLE, it may go as low as $5 to $7 million. I am talking about the second generation. I won't try to guess the 100th unit generation. We have some figures, but I don't know what the confidence level is in these figures. We may speak about 3-5 cents a kilowatthour, but it has to be confirmed.

Q. What is the electrical starting means of the system? What type or where is it connected to the utility system? Presumably to the transmission system in the area?

A. The question is how is it integrated into the grid?

Q. Yes. Is it connected to a transmission system in the area?

A. There is a 69 kilovolt line near the site. There is a small transformer to the line.

Q. What is the starting means? How are you going to start it?

A. In the motoring system; the generator will work as a motor and start the rotor until the wind takes over. Other questions?

Monique Carpentier

Thank you very much. I am sure that next summertime, many people will have a holiday destination all made up for you.

PROJET
ÉOLE

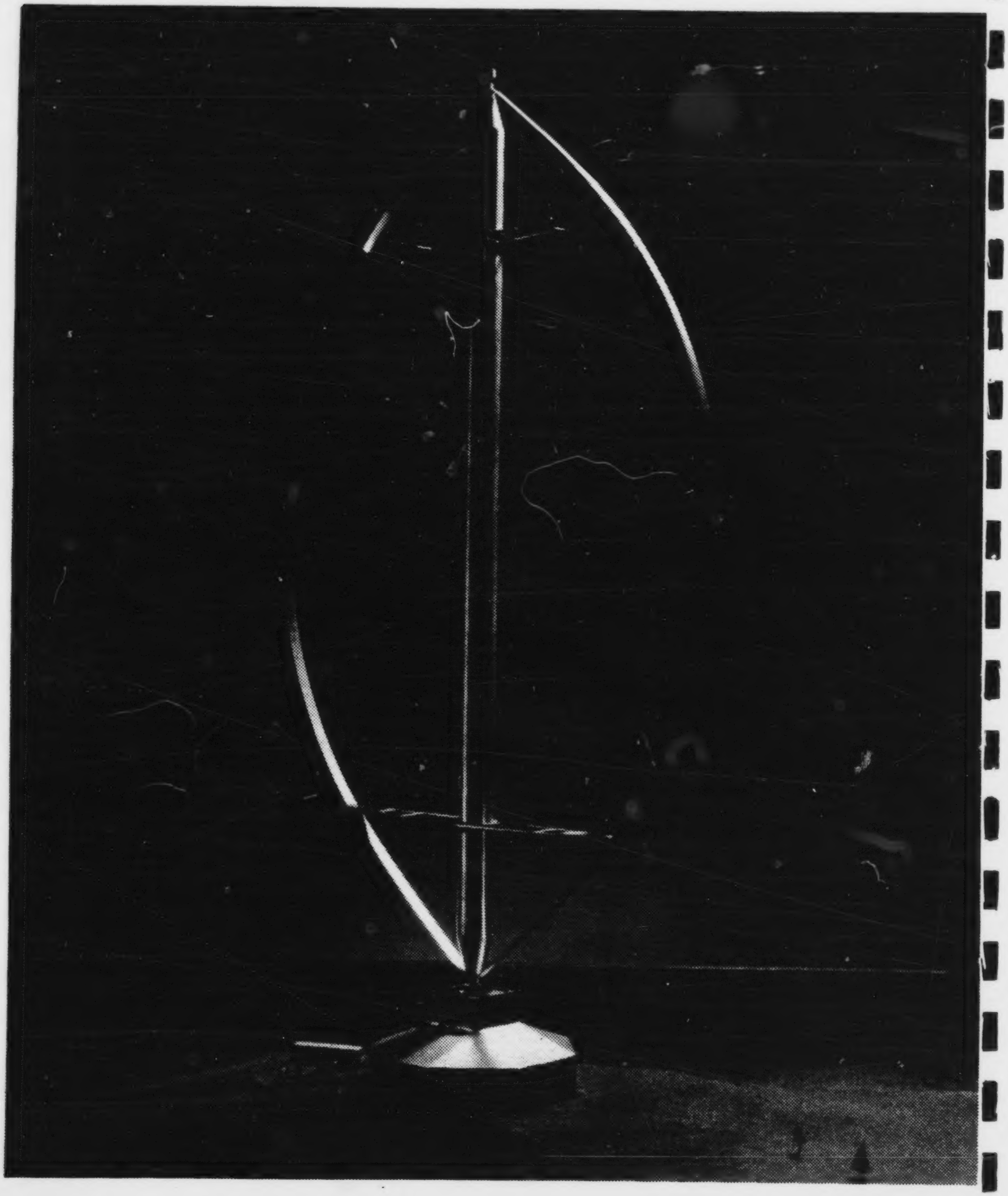


Figure: 1   Projet EOLE - Model Showing Proportions

Figure: 2

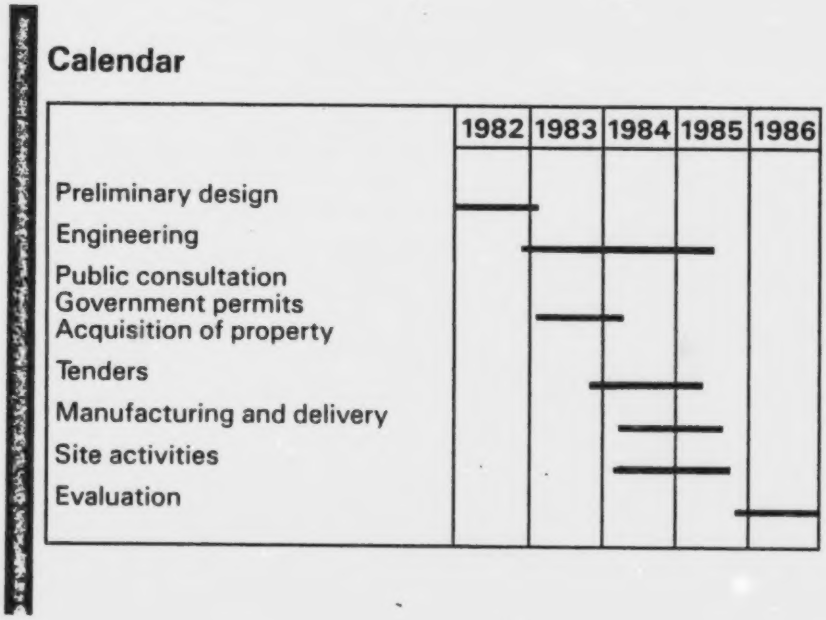

Calendar
1982
1983
1984
1985
1986
Preliminary design
Engineering
Public consultation
Government permits
Acquisition of property
Tenders
Manufacturing and delivery
Site activities
Evaluation

Figure: 3

ANNUAL COST DISTRIBUTION
(in million current dollars)

Total	1981	1982	1983	1984	1985	1986
35.2	0.5	2.9	4.3	10.5	14.0	3.0

Figure: 4

COST SUMMARY

(in million current dollars)

TOTAL : 35.2

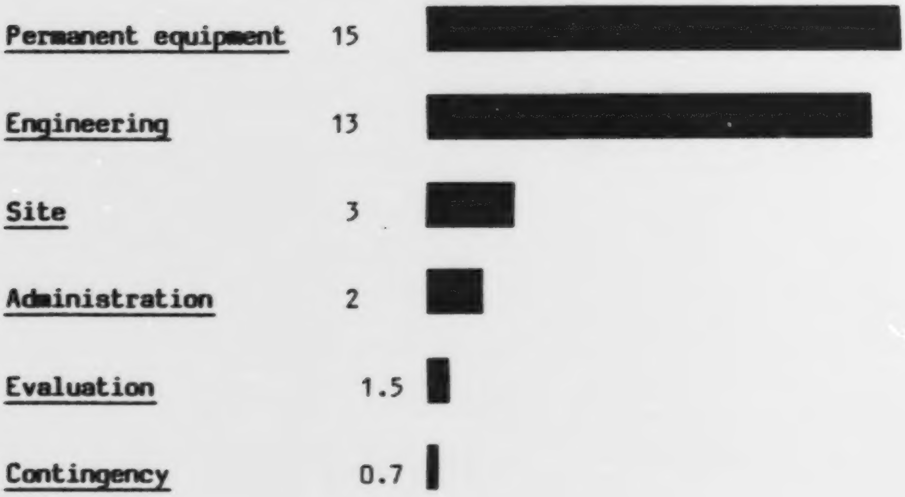


Figure: 5

PERMANENT EQUIPEMENT
COST SUMMARY

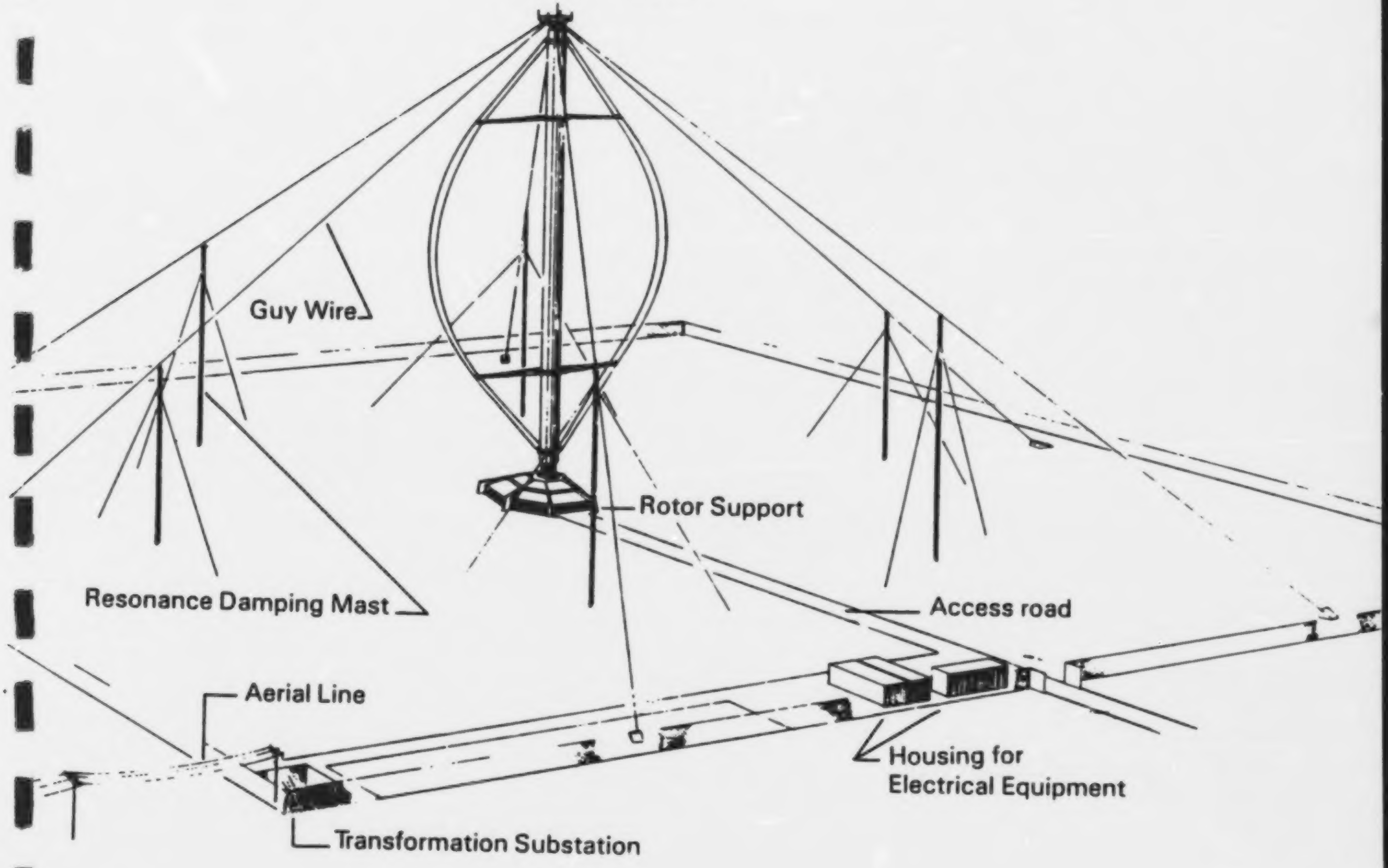
(in million current dollars)

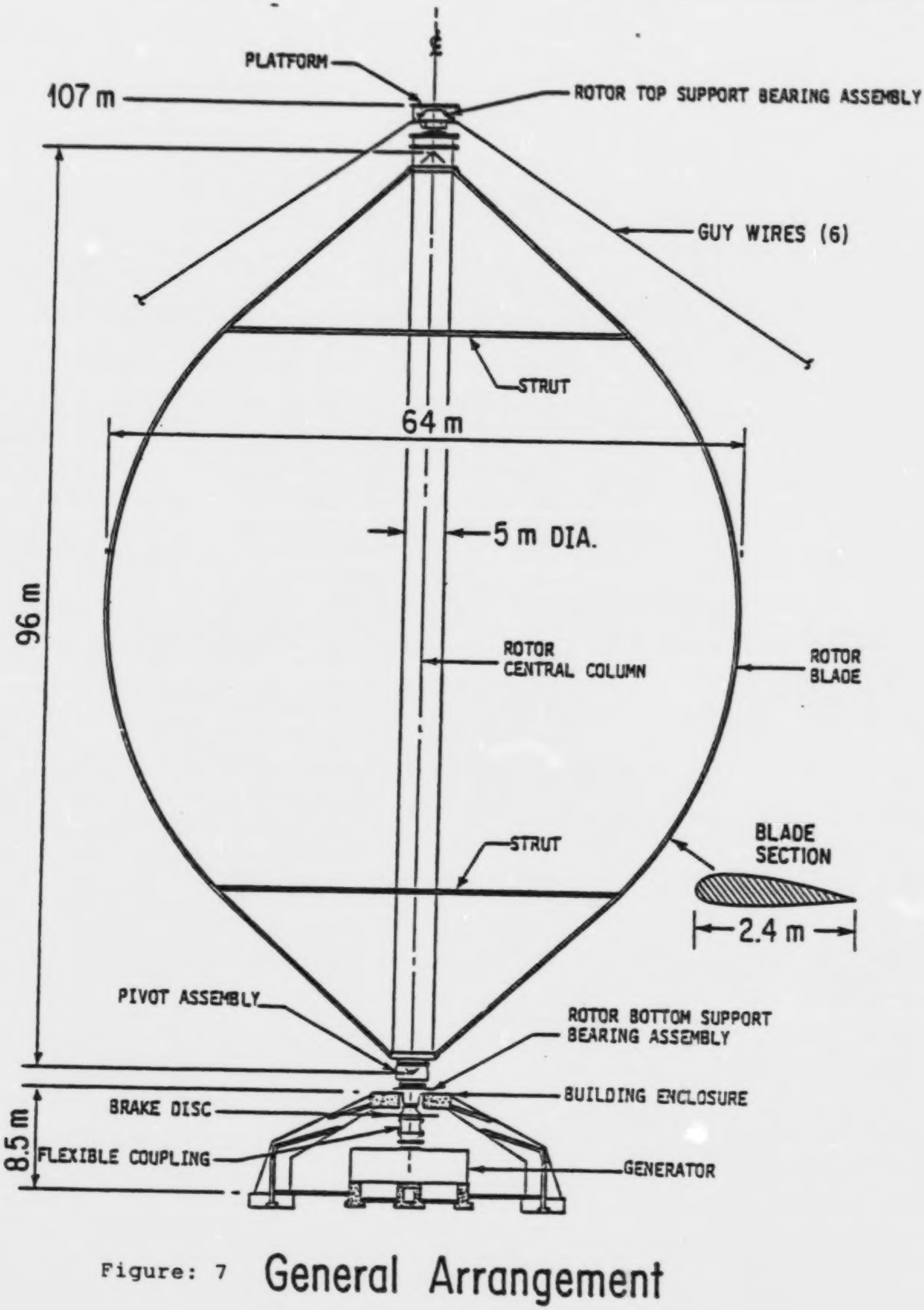
TOTAL COST : 15

Rotor	5
All electrical	7
Drive train	2
Misc. & Instrumentation	1

Figure: 6

General Layout


Guy Wire
Rotor Support
Resonance Damping Mast
Access road
Aerial Line
Housing for Electrical Equipment
Transformation Substation



℄
PLATFORM
107 m
ROTOR TOP SUPPORT BEARING ASSEMBLY
GUY WIRES (6)
STRUT
64 m
5 m DIA.
96 m
ROTOR CENTRAL COLUMN
ROTOR BLADE
STRUT
BLADE SECTION
2.4 m
PIVOT ASSEMBLY
ROTOR BOTTOM SUPPORT BEARING ASSEMBLY
BUILDING ENCLOSURE
BRAKE DISC
8.5 m
FLEXIBLE COUPLING
GENERATOR

Figure: 7 General Arrangement

Figure: 8 **General Arrangement of building enclosure & power train**

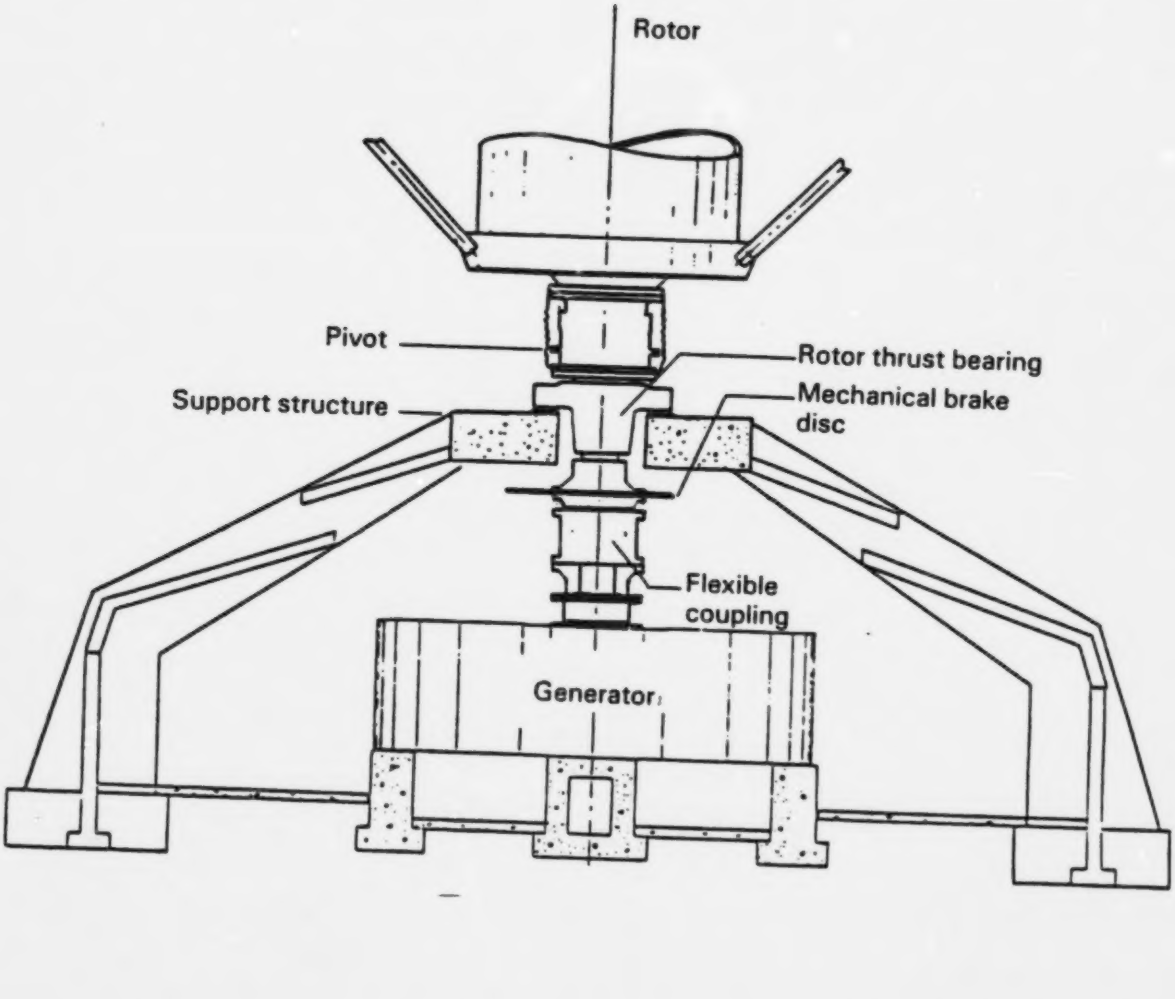

Rotor
Pivot
Rotor thrust bearing
Support structure
Mechanical brake disc
Flexible coupling
Generator

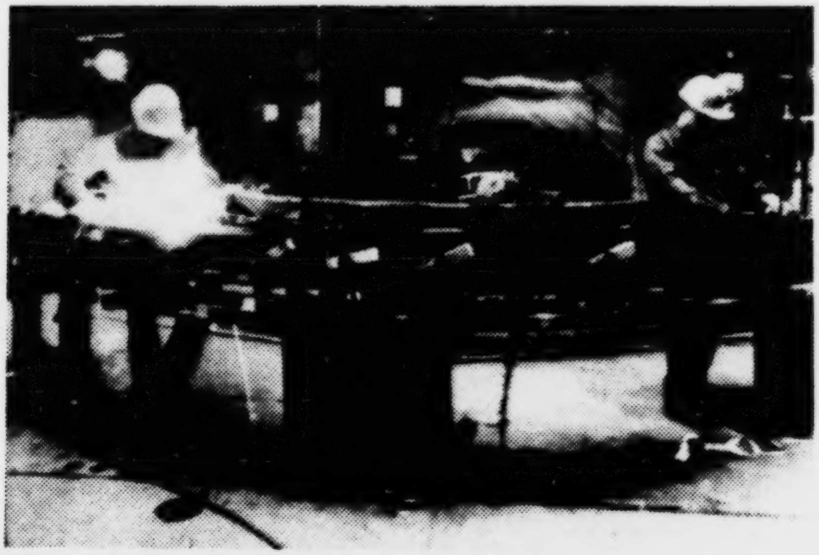
Figure: 9

ÉOLE

SUB SYSTEM	SUPPLIER	KEY DATES	
Rotor	Versatile Vickers Inc.	Adjudication	Apr. 84
		Begin. fab.	Oct. 84
		Beg. site assembly	May 85
		Final assembly	Oct. 85
Guying system	To come	Adj.	-
		Delivery	May 85

Versatile Vickers

Figure: 10



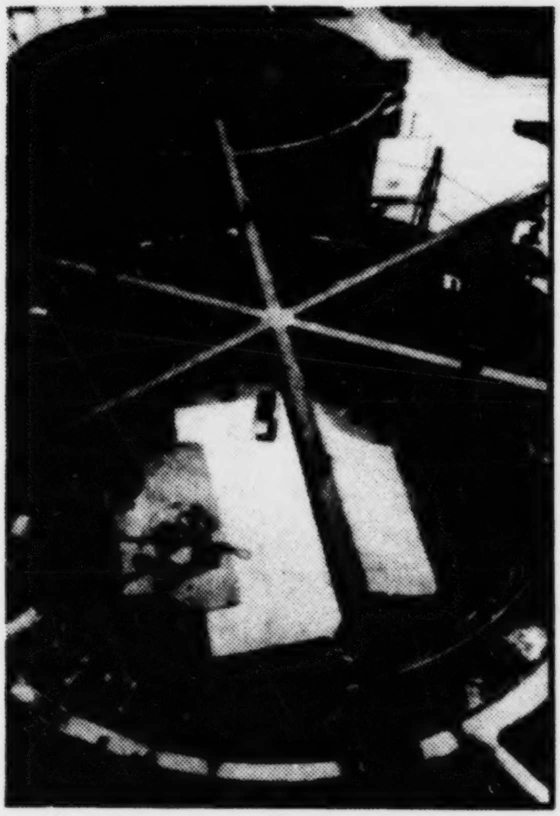


Figure: 11

Figure: 12

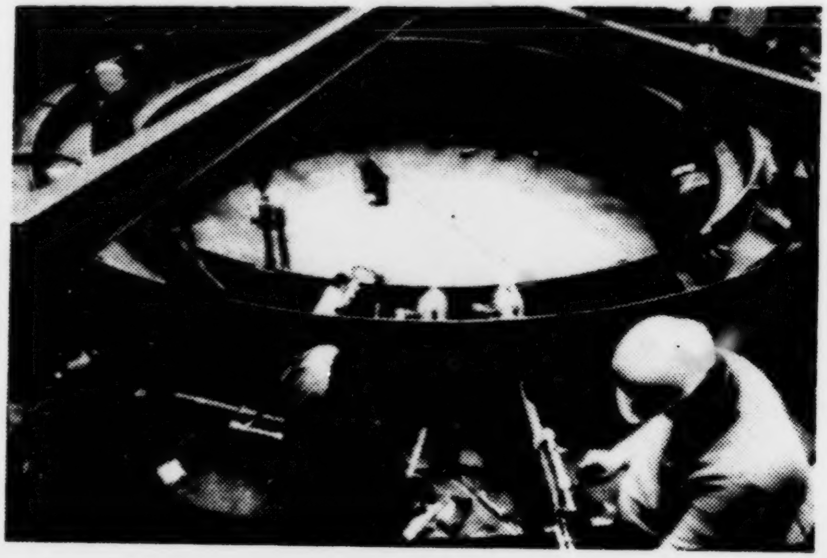


Figure: 13

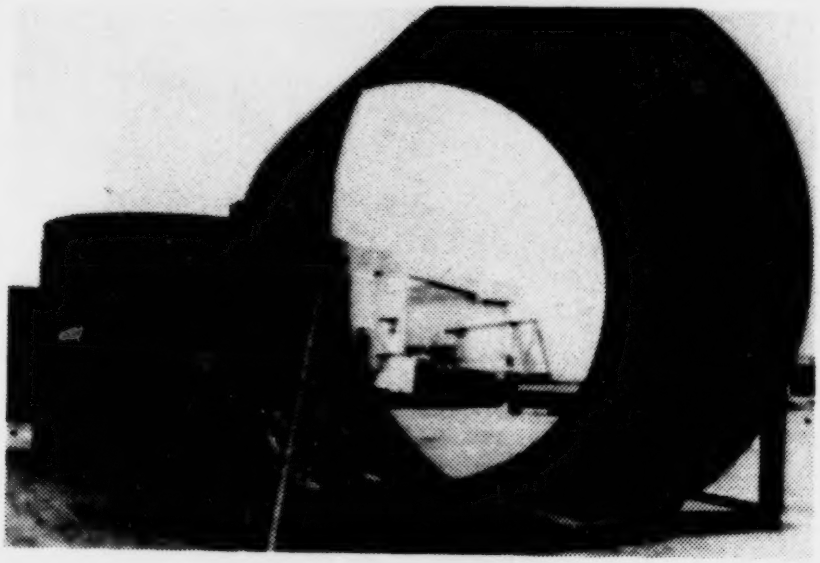


Figure: 14

SUB SYSTEM	SUPPLIER	KEY DATES	
Pivot	Hayes Dana Inc.	Adj.	July 84
		Begin. fab.	Nov. 84
		Delivery	May 85
Brakes	Hayes Dana Inc.	Adj.	Oct. 84
		Begin. fab.	Jan. 85
		Delivery	May 85
Flexible coupling	Hayes Dana Inc.	Adj.	Oct. 84
		Begin. fab.	Jan. 85
		Delivery	May 85
Installation, Drive train	To come	-	-

Hayes Dana Inc.

Figure: 15

Figure: 16

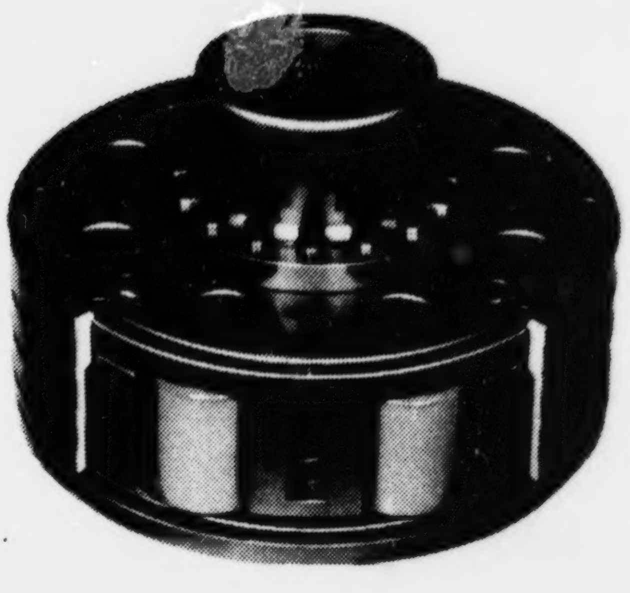


Figure: 17

SUB SYSTEM	SUPPLIER	KEY DATES	
Electrical and control instrumentation	Canadian general Electric	Adj.	Apr. 84
		Beg. fab.	Aug. 84
		Beg. assembly	May 85
		Final assembly	Sept. 85
Misc. instrumentation	To come	-	-

Figure: 18

Canadian
General
Electric

Figure: 19

Figure: 20

Canadian General Electric

Figure: 21

Figure: 22

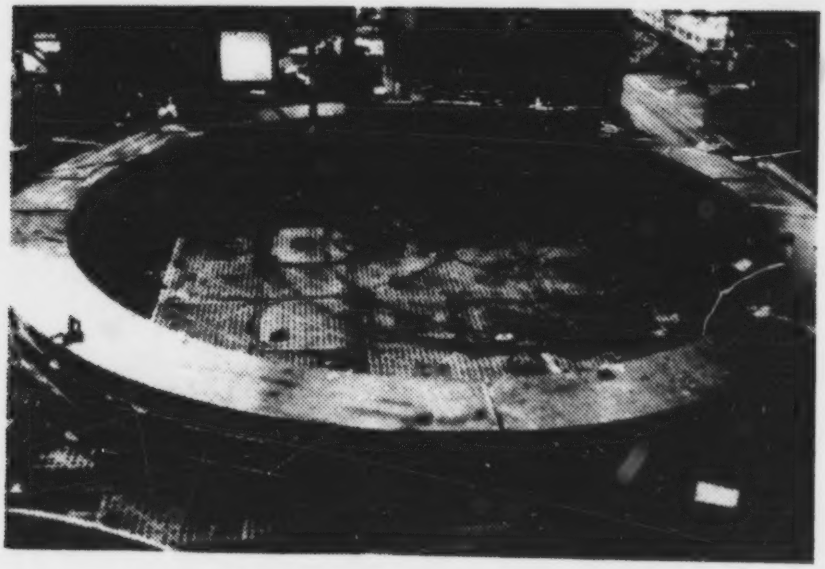


Figure: 23

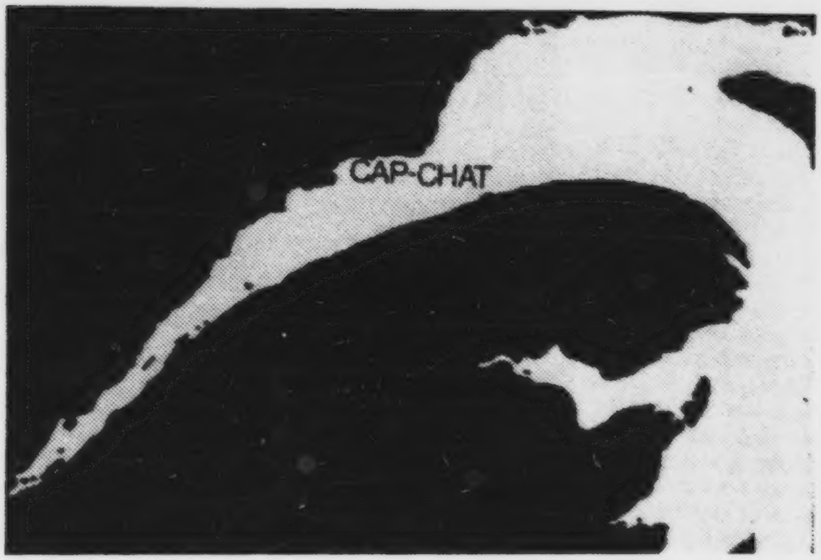
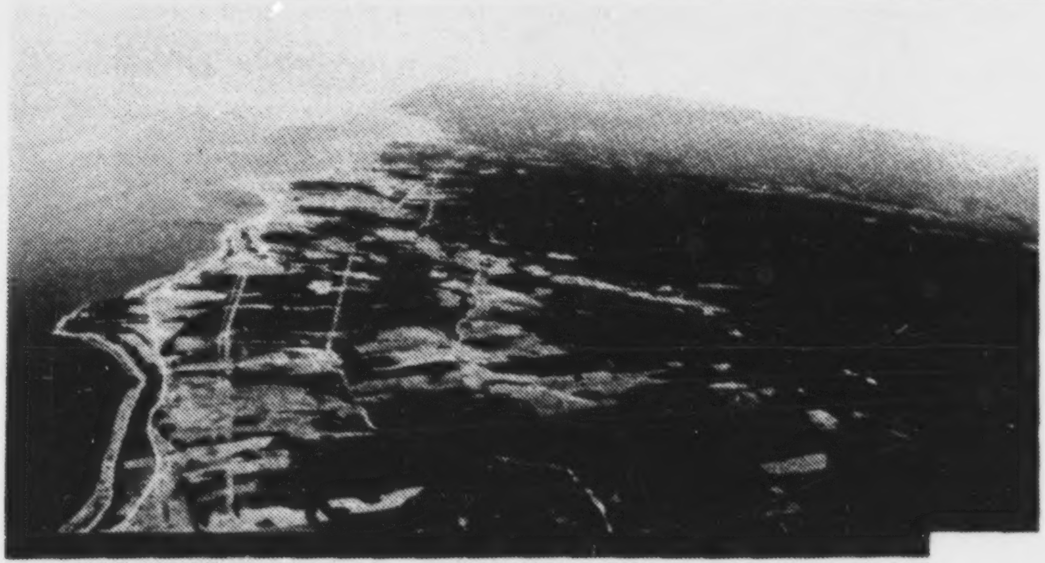
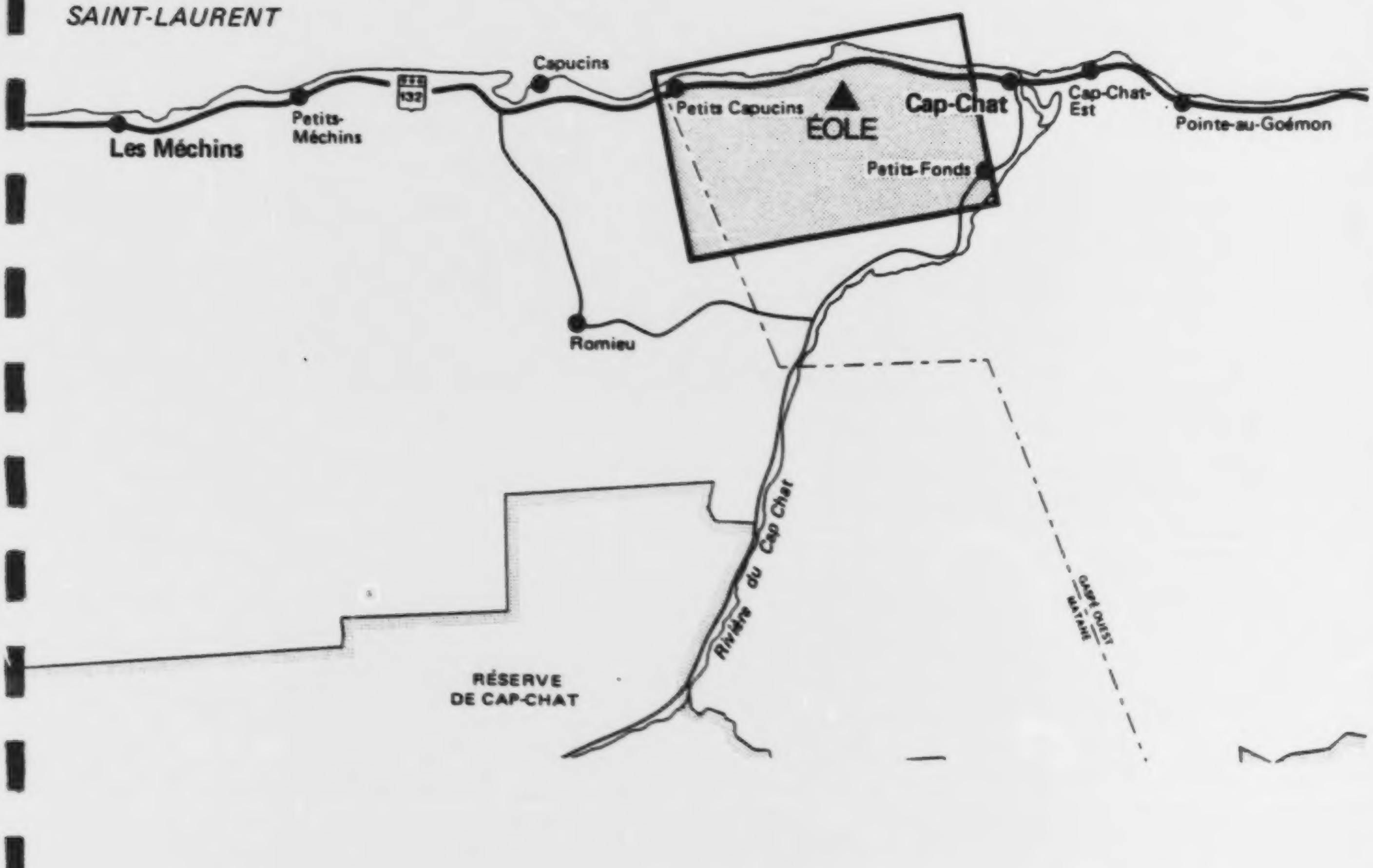


Figure: 25



Vue aérienne de Cap-Chat

Figure: 24


SAINT-LAURENT
Capucins
132
Petits Capucins
ÉOLE
Cap-Chat
Cap-Chat-Est
Pointe-au-Goémon
Les Méchins
Petits-Méchins
Petits-Fonds
Romieu
Rivière du Cap Chat
GASPÉ OUEST
MATANE
RÉSERVE DE CAP-CHAT

Site Construction Progress

Figure: 26

Figure: 27

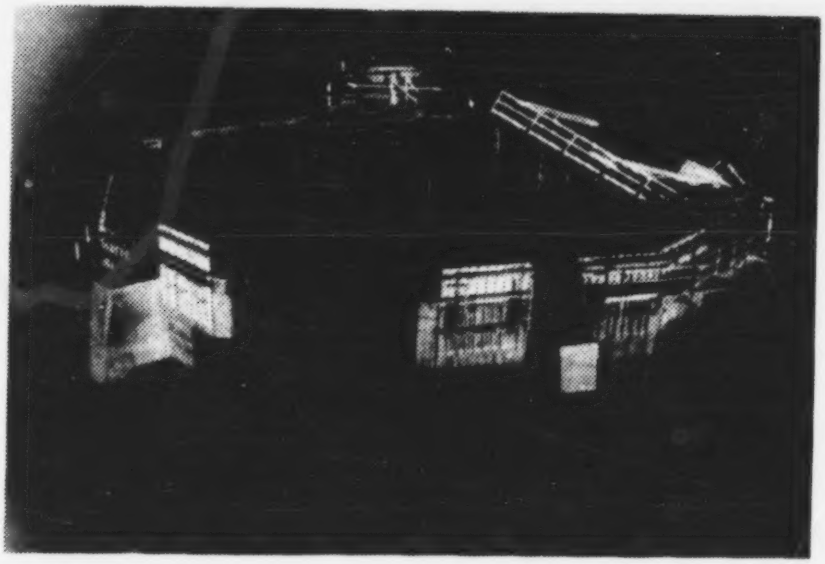


Figure: 28

Figure: 29

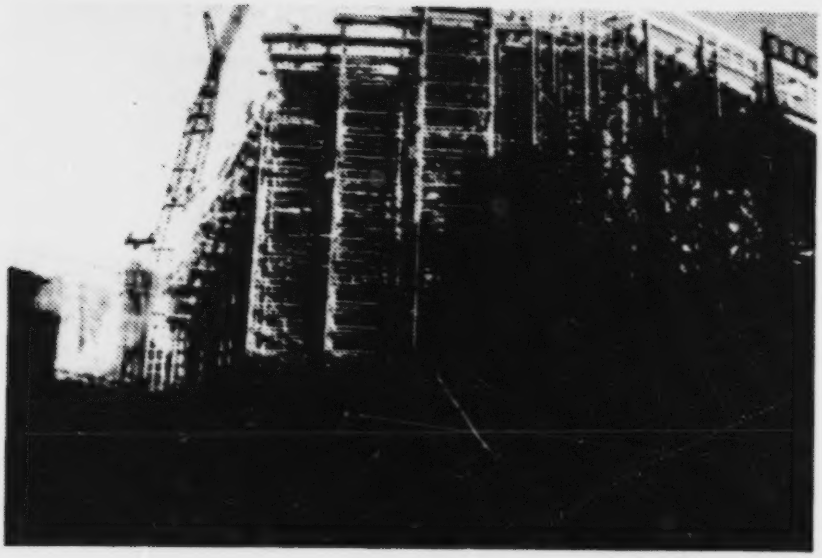


Figure: 30

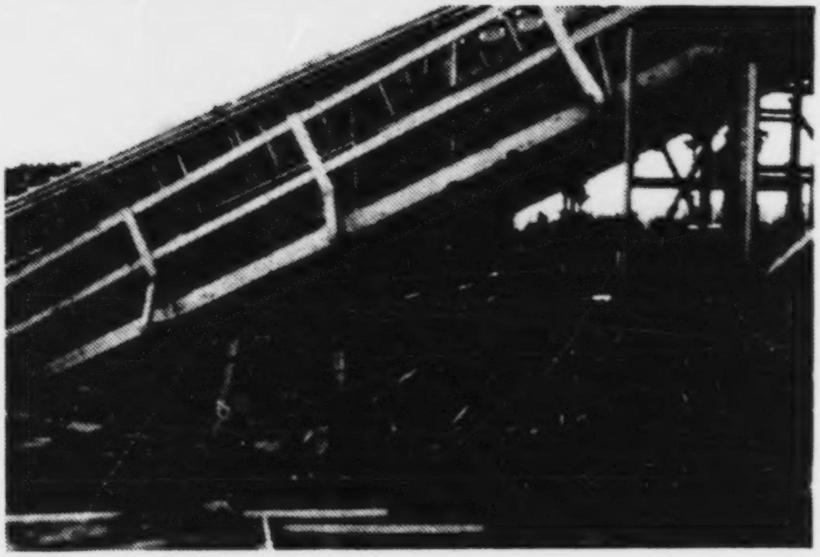


Figure: 31

Figure: 32

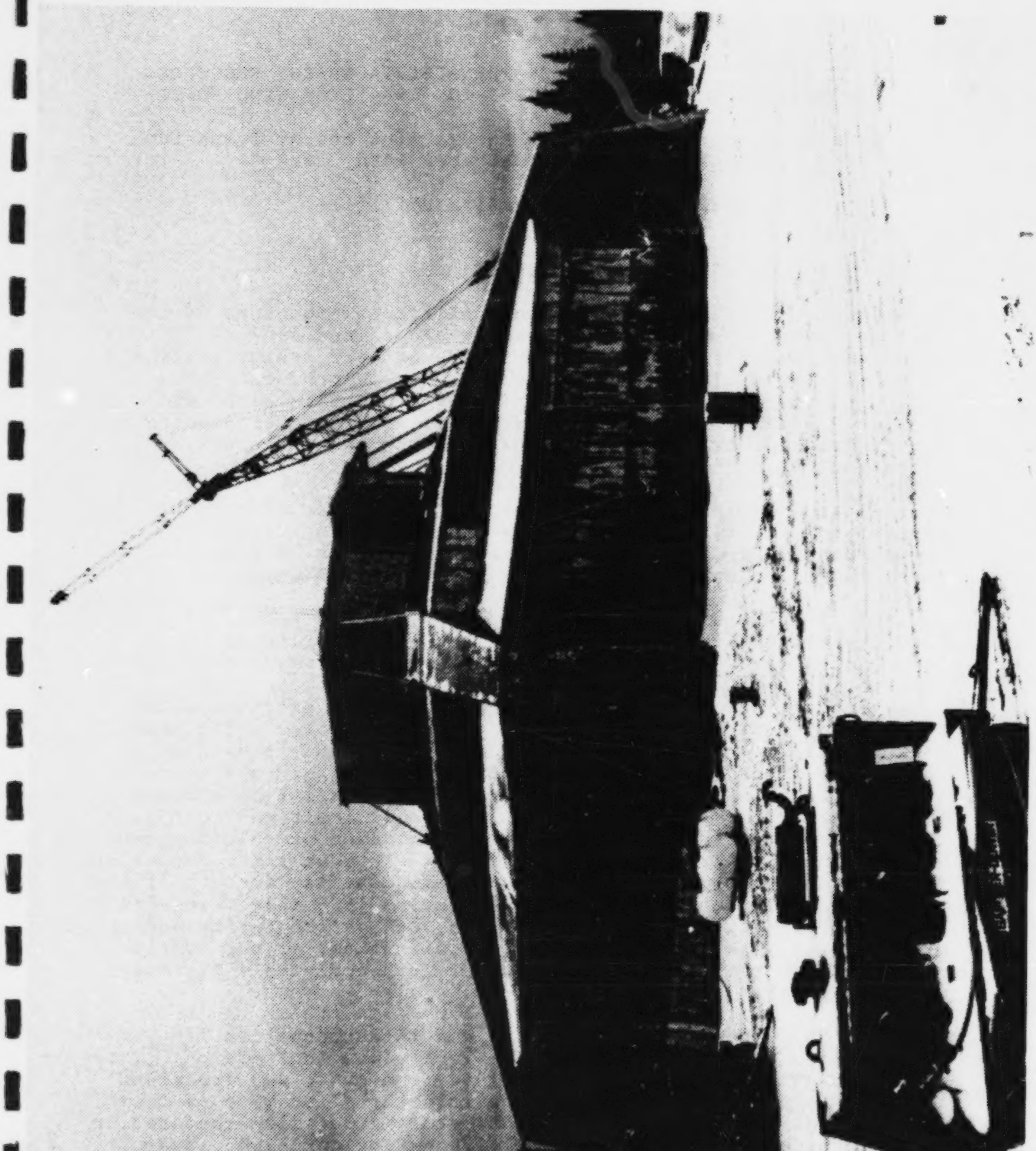


Figure: 33

THE UTILITIES' PERSPECTIVE ON THE ALBERTA ENERGY RESOURCES CONSERVATION BOARD (AERCB) DECISION D84-12 ON WIND POWER

A presentation to the Seventh Annual Wind Energy Symposium
Toronto, Ontario - December 10th, 1984

H.D. Miller, TransAlta Utilities

ABSTRACT

Uncertainty, increasing costs and conflicting arguments of the past few years in the field of energy has caused some organizations and individuals to reassess their energy needs and in some cases evaluate alternative methods of producing and saving energy. Electricity is no exception. This paper will outline TransAlta Utilities' experience in wind power leading up to the decision by the Alberta Energy Resources Conservation Board (AERCB).

TransAlta Utilities is the largest of three major electrical generating utilities in Alberta generating approximately 70% of the power required. Over 90% of this generation is from coal fired thermal plants.

In 1981, TransAlta began receiving an increasing number of inquiries on customer owned generation, the majority of which were wind power. It became apparent that there was a need for information on the fundamentals of wind power and interconnection. TransAlta jointly developed a brochure with Alberta Agriculture: 'An Introduction to Wind Power - Its Uses and Potential'. In 1982, a Task Force was formed to develop a policy for interconnection and pricing. It was at this point that the University of Calgary approached TransAlta to support the installation and monitoring of a VAWT at their environmental research station in Kananaskis. Work proceeded on this for two years. In 1983, TransAlta produced guidelines on interconnection for small power producers which is a more detailed account of the technical requirements. It was also during 1983 that TransAlta became involved in other wind projects such as the Lethbridge Wind Pumping test site; a wind prospecting study at our hydro sites; and an evaluation of wind power for supply to a microwave repeater station.

Late in 1983, the first application and interconnection in Alberta of a SWECS for customer use took place in Cardston. This was followed by two more in early 1984, one owner who proceeded to apply to the AERCB for a hearing into the allocation of costs. The hearing took place in March 1984 and the decision rendered in June addressed the three issues of: rates for purchased power, costs of interconnection and insurance. It introduced a concept of banking, something new to the industry.

The future of rates for wind power appears to be settled for five

years in Alberta because of this decision. It remains to be seen if the decision has improved the economics sufficiently to encourage other entrepreneurs to venture into the wind power industry.

Presentation

We've all seen the confrontations and struggles to some degree in the United States between the wind power industry and the electric utilities. I hope that perhaps some of the information I am about to provide you with today will allow us in Canada to avoid similar circumstances.

First of all, in addition to what perhaps, is illustrated in the title, I'd like to talk about a review of the Canadian Electrical Association (CEA) work that was done this past year. I want to quickly review a particular project which indicated some policies for interconnection for small power producers of electric utilities. This will give you some ideas of what those policies are across the country. I then want to go on to show you some of the involvement that TransAlta Utilities has in regards to wind power. This leads up to the Alberta Energy Resources Conservation Board hearing that took place in March of 1984 and the resulting decisions, some of the things that we were directed to do because of that in general. I think Jason is certainly going to come on after and give his perspective on this whole area of the decision on the wind industry in Alberta and perhaps in Canada.

The major members of the Canadian Electrical Association, as some of you may be aware, are the electric utilities of Canada. They have a very active Research and Development programme, of which I have previously made mention. One of the recent projects that was completed this year was a small survey that was done by TransAlta for the CEA on utility policies for small power producers. I have some of the results here with me today. In fact, some of the copies of the report were handed out by one of the managers who's been here with us the last couple of days. The copies of further reports, if anyone would like a copy, are available from the CEA head office. You can see myself or that particular person afterwards.

These are essentially the major electric utilities in the country that responded to the survey from the east coast to the west. From the small, but no less important, to the larger ones, you'll see that there's quite a variance in their policies. We asked the question: 'How many of the electric utilities permit interconnection of one sort or another?' The answer in every case was "yes"! They did permit interconnection of one sort or another but there were certainly qualifiers to that.

We asked them 'How many purchase power?' You can see right away that just slightly over about 65 per cent of those utilities did purchase power and slightly over 30 per cent did not purchase power. This can be a little misleading. A couple of utilities actually would interconnect for the smaller generators but they answered that they did not purchase power. In actual fact, they just let the meter run backwards which is really doing the same thing. However, they answered "no", so that's a little misleading.

We looked at capacity credit. I'll explain this a little bit further on for those who are not quite clear on it. Essentially, allowing a capacity worth in addition to an energy cost for purchased power. You can see that about 20 per cent said that they did allow a capacity credit to a certain degree. We got a "no" response from 20 per cent, as well. I'm not sure why that came about.

The rates across the country varied drastically. That's not surprising, because the retail rates for electric energy vary drastically across the country. I think we are all quite aware that this particular utility that pays 6 cents per kilowatt hour also has a retail rate up here somewhere. Of course, the one that seems to pay the least in this graph probably has the lowest retail rates as well, when you check down there. It's not too distinguishable here, but there's a range from B.C. Oh, that's a very small one there, let's take another one. New Brunswick Power has a range from about 1.2 to about 3 cents which depends upon the type of generator. It wasn't just a flat rate across the board.

The reasons varied for these and how they were derived, as did the number of rates we had. Some of them used a 'trailing step', a retail rate that they had. Some used the price of their cheapest energy. Others looked at 70 per cent of the replacement costs, I guess to cover their own overhead and administration costs. One of the more popular ones, as we already know south of the border, has been 'avoided fuel cost', or if you looked in some cases, just 'avoided cost'. Wholesale less administrative costs, the average cost of generation, there's different derivations of all these different rates.

One of the other items that keeps coming up is as follows. There are additional costs when you interconnect with a small power producer. Who should pay for those costs? In 80 per cent of the cases they indicated that the customer, or the small power producer would be responsible for those extra costs. Again we had a small "no" percentage.

Just a couple of other items. Regulation was one that came up. A question we asked was "Are these interconnections regulated and if so, any comments?" They indicated that across Canada there seemed to be some form of regulation. In the majority of cases, as can be seen here, almost 90 per cent either had some form of Energy Board or Public Utilities Board that controlled the rates and the interconnections to purchase power.

Okay, that pretty much wraps up that particular part. There is a bit more information in that report which I think is fairly interesting. It is available from the Canadian Electrical Association.

The work and activity, that has been going on in wind power in Alberta, has increased dramatically in the last three years. This particular graph is just one indicator, of course. It is a graph of a number of copies of a particular brochure that has been distributed lately. We have a copy of it here and they are available outside on the table should anyone want one. It is just a very basic introduction to wind power, its uses and potential. It was a joint publication between Alberta Agriculture and ourselves. It discusses the different machines and the different decisions that perhaps one is confronted with. Hopefully it provides some of the answers. It also has a very brief outline of the interconnection policy of the electric utility. The policy covers those two things which are first and foremost in everyone's mind: technical requirements and energy pricing.

We also have available another book, though I don't have any with me today, which is a more detailed book on guidelines for small power producers.

All this activity led late last year to the first interconnected wind turbine in Alberta, a small 5 kilowatt Enertech unit in Cardston. Further to that, a couple more came onstream, including a larger three phase unit in February. When that happened that particular applicant made application to the Alberta Energy Resources Conservation Board, which, among other things, administers the Hydro-electric Energy Act in Alberta. He made application for a hearing, essentially, to request that the board address matters relating to the allocation of costs, and other terms and conditions associated with interconnection.

The hearing took place in March. It had six intervenors, besides the applicant. TransAlta Utilities was an intervenor. Nor'Wester Energy Systems and Jason Edworthy intervened as well as four others.

TransAlta's position at the hearing, essentially, was that we supported the principle of customer-owned generation and took the position that any customer may interconnect and operate electrical generation in parallel with our system. However, in order to be fair to the rest of our customers, we felt that while we were prepared to purchase all of the applicant's energy in this particular case, it would be at a price equivalent to the 'avoided energy cost' on our system. There were a number of other factors involved, but essentially that was the position that TransAlta took. I am sure that Jason will outline to you the part of his position, at least, that he took in his presentation.

This is the item in question, or it was at least at the time. I thought I might get through a presentation on wind power at a wind symposium and be the only one without showing a wind turbine, but that's not the case. The one I am showing is in Pincher Creek about 100 miles south of Calgary, for those of you not familiar with the area. It is, as I say , a 40 kilowatt, three phase Enertech machine. It is interconnected at 25KV with the TransAlta system in that particular area.

The hearing took a total of two full days. You can see the sheer size of the transcripts that resulted from this hearing and some of the things in there that came out of it. A news release came out of it on the 12th of June indicating their particular decision.

I just want to give you some of the conclusions of the Alberta Energy Resources Conservation Board regarding this particular applicant. It felt that there were three main points that were addressed which it commented on in the results of the hearing.

Point one, was that a small power producer generating wind power energy, cannot fully utilize and conserve such energy for his own purposes without some means of matching the availability of that energy to the small power producer's own load. Such means of matching are not available at reasonable cost, independent of a large interconnected system.

Point two, was that an electric utility is a customer-oriented, regulated enterprise that provides needed electrical service at the lowest reasonable cost. However, we hear today that electrical utilities have been innovative in meeting the demands of their customers through new types of services and the development of new forms of contracts that recognize the true cost of providing services.

The third point, that the Board outlined was that the parties agree in the hearing that they should not subsidize one another. Each should be able to pursue its business without acquiring costs or benefits from the other party. There appeared to be no quarrel with charging or paying for actual costs or benefits. What disagreement there was, arose from the different understanding and perceptions of impacts, costs and benefits. I will leave you to think about what all that meant for a few minutes.

There are three items that we felt were really ruled on in this particular case: purchase power rates, interconnection costs and insurance.

In reverse order, insurance. I shouldn't say the Board ruled on these three, it made statements on these three...insurance it wouldn't touch. The Board said that should be worked out between the two parties.

For interconnection costs, its decision was that the small power producer or the WECS owner in this particular case, should pay for any costs over and above the standard costs of service.

The purchase power rates became the hottest item in the hearing. In the ruling, what the Board did was introduce a fairly unique, innovative concept that it called banking. I'll describe that quickly for you.

For banking, essentially what the Board did was establish a three month credit period. During this period, the wind power producer could generate as much electricity as is needed for his own facilities and bank, if you like, the rest of the energy in the electrical system. During that three month period, he could then draw on that credit up to the point, obviously, of what he had banked - just like a bank account.

At the end of that three month period, the bank account was balanced or cleared, if you like. The credit that he had established on any excess energy, that he had not drawn on, was then paid for at a rate that the Board directed. I'll get to that in a minute what that rate was. But, at any rate, if he had emptied his account, if you like, before that period then, essentially, he would pay for any extra power at the standard retail rate. In effect what is happening, is that the credit system allowed the small power producer to receive any energy he put into the system at the standard retail rate up to the amount he banked. This just quickly gives you the price of purchased energy for any of the excess energy that he had in the system. It's just his credit line drawn at the net energy times 1.6 cents, which was the price that has been established as the avoided fuel cost on the Alberta interconnected system.

These are some of the technical requirements that we looked at: metering, safety, switching, maintenance and other system considerations. I think you have all been overwhlelmed with a lot of the technical aspects of this particular item.

This is a term decision. In other words it goes on for only a maximum period of five years, a trial period, to determine in actual fact a lot of the things that weren't able to be determined at the hearing. That five years could be reduced if the number of units reaches 150, or the total capacity on the system from wind generators reaches 10 megawatts.

What it really did was, I think, encourage a little more wind systems on the interconnected systems. For the small power producer, it will certainly improve his economics somewhat, but it did not encourage the concept of wind farms for people installing wind turbines strictly for profit or becoming a utility for that purpose. This really did not encourage that particular aspect.

The second part of this procedure decision directed us to monitor these sites. This looks like a little wind farm in southern Alberta, until you realize they are over 100 miles apart. We do have six interconnected wind turbines in Alberta: two down Cardston way, a couple in Pincher Creek, one test location in Lethbridge and one outside of Calgary which is Mr. Edworthy's. We have been directed to monitor in some detail the energy being produced from the three in our interconnected system for the five year period. This includes perhaps any more that may come along during that five year period, if it is deemed necessary by the Board.

This must be done totally at the utility's cost. We are another casualty of the demise of the Division of Energy in the National Research Council. There was some partial funding on its way, which didn't quite get out of the city limits of Ottawa before it was hauled back. We are still stuck with performing that function ourselves, or at least paying for it ourselves.

Just to give you some quick figures, on that particular turbine, I showed you. We've had some metering in there, for instance, for a 4 month period from June to November of this year. The total kilowatt-hours generated by that 40 kilowatt unit was 31,288. The total load to the particular load at that farm location was only 6,460 kilowatt hours. You can see that there was quite an excess of energy there. However, this particular farmer is intending on expanding, electrically, his business - at least to be able to use more of the wind-generated electric power.

At the beginning, I tried to indicate and offer the hope that some of what I was about to tell you would help us in Canada avoid some of the problems that the United States has experienced with some of the legislation and regulations there. I think the events of the past year in Alberta are a first step in that direction.

Thank you very much.

THE ALBERTA ENERGY RESOURCES CONSERVATION BOARD DECISION: THE WIND INDUSTRY PERSPECTIVE

Jason Edworthy, Nor'wester Energy Systems

ABSTRACT

The use of wind energy has a long history in Alberta, dating back into the last century with water pumpers and in the first few decades of this century with rural use of Winchargers and Jacobs windplants. Within the last decade, there have been a number of modern wind energy installations in Alberta - mostly remote, battery charging windplant systems. However, a small number of utility-connected experiments were carried out, unsuccessfully.

During the late 1970's, growing interest in this activity, coupled with the success with the technology in the United States, caused a number of interest groups to evaluate and press for utility grid connection of Small Wind Energy Conversion Systems. About this time, the Alberta Research Council's Solar and Wind Energy Research Program (SWERP) became active.

In 1981, TransAlta Utilities Corporation announced a policy permitting utility-connection of small windplants (Small Power Producers - SPP). By early 1984, five installations were operating in Alberta, among them, the largest privately owned windplant in Canada.

Philosophical and economic differences between this SPP and TransAlta Utilities caused an application for a hearing to be made to the Energy Resources Conservation Board, which is responsible for overseeing most energy-related facilities in Alberta.

The hearing participants discussed the impact of the windplant on the utility, environmental aspects of wind power, economic implications of a growing wind industry, value of wind energy and economic responsibilities of all parties.

The Board decision affects the wind energy industry and users in a strong and positive manner. The value of surplus electricity and the aesthetic and intrinsic values of wind energy, which were recognized by the Board, are important. It is necessary that the industry and users make a strong effort to show responsible actions in dealing with the utilities, the public and government agencies in order to sustain and protect the positive perspective now established.

This presentation will illustrate the important points of this decision and will relate wind energy perspectives regarding the hearing process and the impacts of the decision on the wind energy industry and wind energy users.

Presentation

I am very honoured to have been invited to speak here at the symposium. I think this is a very important event this year with the Charter Meeting of CANWEA at the Seventh Wind Energy Symposium. It is extremely important. I'm glad to see the turn-out we did have. I wish we had more. I think that's up to every one of us who are attending here this week to go out and encourage all the people we know, whether through customer relations, even relatives, if necessary, to get out and support CANWEA in the future. I might say, though it's been said before, that since the funding situation is changing radically, it is awful timely to have CANWEA starting in late 1984. I am not discouraged by that situation and I hope that by the end of my presentation you will see why. I believe that wind energy in Canada, certainly in Alberta, is presently economical, presently viable and is presently being used. This will only continue to grow.

I am going to start out by presenting some of the history of wind energy use in Alberta. This will lead up to the hearing and the decision. Finally, I will try to concentrate on the wind energy perspective of where I believe the future is after the decision.

We've taken some care not to overlap in our presentation. Please excuse us if Dave and I have done so, a little bit. Hopefully, if we do, it will only be in points that perhaps need emphasis or clarification as time goes on. Can we have the lights dimmed, please.

As everyone knows, in Alberta, in the prairie regions, in Ontario, and in other parts of Canada, the use of wind energy really started out on the farm in many sort of fashions. Chiefly it was applied to water pumping or producing electricity, usually the DC type of electricity before the coming of the REA's (the Rural Electrification Association). I'm not sure if they also came through the rural areas in Ontario to bring grid electricity, but they certainly did in the prairies. Before that, most residents in rural areas got their electricity from either home brew or purchased windmills. This is a refurbished Wincharger, a common scene in the Prairies still today, as were the Jacobs units. Many of these are still in operation across the prairies. Approximately 40 remote units are made from refurbished equipment in Alberta. We even know of one fellow over 80 years old who never got on the grid.

After the oil crunch of the 70's, a lot of experimentation and research came along with the new interest into alternative energy. We all know very well of the NRC's excellent work into vertical axis and other types of wind turbines. In Alberta there was quite a bit of interest as well. A fellow named Larry Peterson worked very hard with a very good idea using recycled helicopter blades on a 7 - 7.5 kilowatt grid interconnected turbine. I believe TransAlta was still called Calgary Power in those days. But, they cooperated fully with Larry's project, which unfortunately never did have any rotation.

A few years later, Mike Youso was managing part of the Kananaskis Environmental Research Centre's energy project in the Rockies west of Calgary. He'd already been running a Wincharger. He was involved with TransAlta in bringing a frontier unit to the Kananaskis site for interconnection. It is approximately a 40 kilowatt, vertical axis type machine. Unfortunately, today it is still not rotated either.

Along with this interest came a lot of interesting remote site installations in Alberta. CBC put up a Northwind HR-2 for a repeater station on Pigeon Mountain on the way up to Banff. Canadian Western Natural Gas did the same thing on Plateau Mountain. NOVA - an Alberta Corporation, put a 5 kilowatt Dunlite out at a gas metering plant on the prairies.

Many private individuals also put up wind plants, whether refurbishing them or putting up new ones.

This is a downtown Regina shot, I got it at the Energex show last June.

This is a home brew mill up in the Yukon.

This is where I got my first start. I put up a Thermax unit with a group of individuals for an Environment Canada research station in the Rockies. Yes, that's a glacier in the background. This was in about 1980.

Also at this time, the push for more grid interconnected activity was coming along in Alberta. Larry Peterson's project was coincidential with this. A few other individuals became known and you have probably heard of some of them in Alberta. One who certainly should have his due here is Jack Otis, who owns Wind Dynamics. He did an awful lot of ground work, sometimes irritating to the utilities. But he certainly made a presence known and he, I think, had a large influence in the resulting policies which TransAlta came out with for interconnection. By the way, TransAlta is the only utility in Alberta to actually publish its own policy on interconnection in a form like this.

As Dave has already outlined, there are a number of machines which were put up, not immediately after, but very soon after the policy was made to allow interconnection. I am sure that everyone is familiar with the installation of a small WECS. It's exciting work when you are up at the top. It has already been mentioned that there are a number of interconnected units in Alberta, six in total right now.

I'd like to discuss a little bit about the interconnection procedures in Alberta because it is not immediately apparent to anyone what an SPP must go through before getting approval and actually putting a machine in. The first and most important thing is to approach the utility and get permission. Two, three utilities, I guess in Alberta, have actually given permission: TransAlta, the city of Calgary Electric System and the Cardston Electrical Distribution System. I might point out that of all those, only TransAlta is actually a producer of electrical energy.

Afterwards, after that has been arranged, the Energy Resources Conservation Board is asked to approve an installation. Wayne Berg, who is in the audience, can answer directly or specifically any questions about that. They basically have a function, as I understand it, to regulate any energy projects which have public impact. In this case, they would regulate utility connected wind plants, not stand alone or battery charging ones. They are certainly interested in those though.

The Public Utility Board (PUB) is another agency in Alberta and they actually are the Board which governs rates and costs. The ERCB tends to be more of a policy making and guideline agency. The PUB does not require an application unless there is any disagreement about rates. Such an application on this topic has not yet been made. However, I have strongly recommended that all wind plant owners notify the PUB of the installation and they seem to be quite happy with that. The final step is if the utility and the SPP are required to come up with a contractual arrangement, then that must be settled between those two parties.

Herein lies the basis for the hearing which has been described.

The basic arguments have been outlined by Dave Miller. Ernie Sinnott and TransAlta really couldn't agree on an SPP contract on the three points mentioned.

On March 20th, when the hearing was called, there were a number of intervenors, or people who spoke, for the following two days. Anybody from the public could apply to be an intervenor. They had to come up with a written and an oral presentation. I should describe, just a little bit, the purpose of an ERCB hearing. I'll quote directly from one of their documents: 'The Purpose'. "Not the least of these purposes is the objective of enhancing the Board's information and understanding as to the matters upon which it must render a decision. In that regard, the Board frequently invites public participation in hearings where the only issues at stake are matters of policy, which the board may wish to use to guide its future decisions."

What I wanted to point out here is that the Board, I believe, is an extremely fair and well-educated group of people who are very willing to listen to all opinions and all ideas. This was certainly well-illustrated at the hearing. They put up with somewhat amateurish presentations as well as extremely professional presentations. They were very fair and kind to everyone. I'll refer to that later when I talk about lessons learned by the wind energy industry in a hearing.

The participants have been listed. The decision came out on June 12th and parts of that decision have been read. I'll read a few other parts:

"The Board believes that Mr. Sinnott's operation should be treated as that of a customer who, by managing his load to conserve energy will reduce his requirements from TransAlta. Furthermore, Mr. Sinnott should be compensated for the surplus energy that he generates by being allowed to bank it in TransAlta's system during periods when his generation exceeds his load. Mr. Sinnott would then be able to use his banked energy during periods of low or zero generation by drawing energy from the TransAlta system."

Then, discussing the billing period:

"If, during each such period, TransAlta is a net supplier of energy to the applicant, then he would be billed for this energy at the usual utility rates. But, if the applicant produces more energy than is his own requirement during the same period, TransAlta would compensate him for such surplus energy at a suitable surplus energy rate."

Another comment is that:

"The Board believes there is some definite, but unquantifiable, capacity contribution made by Mr. Sinnott's wind power generator."

As earlier stated:

"The Board believes there should be a trial or learning period to determine the true impact of the Sinnott installation."

I will add in brackets ("apparently other installations").

"During this period TransAlta should, with the cooperation of the applicant, obtain all the relevant technical and cost information on the operation and interaction of the windpower generator with the TransAlta system, and submit to the Board a report each calendar year and at the end of the period."

Dave has already pointed out that all interconnection costs shall be borne by each party incurring them. Typically this means that interconnection and additional metering costs are borne by the SPP.

I'll just make one final quote here:

"Having considered the evidence, the Board believes that the construction, operation and interconnection of the Sinnott wind power generating facility is in the public interest and consistent with the requirements of the Hydro and Electric Energy Act."

Well, what does this mean now? What are the implications? We've had banking explained by Dave and I think probably it's an easy concept to understand and we'll refer to questions at the end to see if there is anybody who doesn't understand it and hopefully you'll speak up.

One of the requirements that I just read was the metering and monitoring. This is the monitoring at my own site that we are doing with the City of Calgary Electric System. With the assistance of the CEA, there will be a lot of this going on at various levels of sophistication.

Well, as Dave pointed out, the future for windpower in Alberta probably does not mean this at this point. This is an Altamont Pass wind farm with US Windpower. What it certainly has meant already is increased public interest. You saw a little picture of the newspaper clippings. You've probably already seen something in World Wind and in other publications. We are certainly seeing a lot of public interest, as I know TransAlta does.

There is going to be better economics in the installations. The pay-back period for residential installations in Alberta, we reckon to have been bettered by about 20 per cent.

It has also provided a positive atmosphere for individual investment in wind power. There has been a lot of interest, a lot of discussion, a lot of activity. People came out with a very positive attitude towards it.

It's also given a boost and a boon for local research. This is the Lethbridge wind turbine test facility. It received a lot of additional attention as a result too. Interest is very high. I am sure some of the interest has at least rubbed off on the NRC projects. We hope maybe this will help sustain interest wherever this research goes. It's surprisingly leading to bigger machines and more interest in bigger machines in Alberta, but to a limit. We are not yet ready for large machines to feed utility grids, as in a separate utility size, but, rather, large SPP interests. There has certainly been a lot of interest with recent CEA requests for proposals from Alberta and also from Enerdemo.

There's a lot more monitoring going on in many aspects and in many ways: at mountain sites, for utilities, for the Government, for individual users and at the research site at Lethbridge.

It certainly helped our industry, my business, for sure. We do a lot of qualitative, as well as quantitative, site assessment. The interest sparked by this decision and the hearing itself has certainly assisted us there.

There is also more analysis going on. Analysis is getting better, more scientific and better priced. Even, you know, a farmer, a home-owner or a cottage owner can afford to buy a good anaylsis now. The same with economic analysis. The economic analysis is becoming more rigorous. People are demanding it and they are also getting it. This again is part of the result and coincidental with the hearing.

I feel certain that there are more installations coming up. There were more sales this summer, more installations going on, a lot of enquiries through the winter for next year. I know installations are proceeding on a lot of different fronts and there is certainly plenty of work around.

I feel it timely to point out with this joint presentation that one of the latest installations going up in Alberta belongs to TransAlta Utilities. It is at this remote microwave site, which you can just see there. This is a not a grid connected one.

I believe that the spinoff interest to all the industry has spread in all directions, including remote site installations. This is a 10 kilowatt Bergey battery charging installation on a high energy mountain site.

I think eventually it's going to have other spin-offs in Alberta. I've had a lot of people tell me: that their land is available for lease through us; that there are investors needing projects out there, to put wind turbines on wind farms (if they should ever be able to exist!); you name it. We've had groups of doctors and lawyers approach us with money for investment. There already is and will continue to be more hybrid interest. There definitely is interest in wind farms, even though the decision has not really changed the economics in Alberta, or even the possibility of that too much.

What does this really mean to the wind energy business in Alberta, and in Canada?

Well, for small companies, dealerships, manufacturers, consulting companies, I think there is a lot of business. I think that the Energy Resources Conservation Board hearing and decision gave us all a chance to think out our arguments very, very clearly, lay them on the table and compare them with other people's. There were a few surprises.

We received from this Alberta Government agency the recognition, from a wind energy viewpoint, of some of the arguments we said. I read to you a quote saying that yes, there is a capacity there...it's not quantifiable yet. Hopefully the trial period will help nail that down. There is some concern for environmental values and aesthetic values. Those were mentioned quite frequently and were given some recognition. This coincides with the soft technology path of renewable energy, although it wasn't stated outright. There were considerations given to the economics. During the hearing there was a lot of discussion about the economics of machines, a number of presentations by economists and non-economists.

Is this decision a precedent-setting one for the rest of Canada? I'm not sure. I'm not sure that another hearing or even a Court would take the ERCB decision as a precedent for it's decision-making. I'd certainly like to know whether it is, and I believe Malcolm is considering it in some activity going on in the Maritimes. I believe it has led to a greater general acceptance of the technology, certainly in Alberta. There was, this summer, a headline in a newspaper out of Cochrane, a town near Calgary, which read: "They're Not Laughing At Windmills Any More".

As I mentioned , it leads to greater economy, better pay-back. The present situation for a commercially owned installation in Alberta is now a pay-back, I believe, of five to seven years. For residential installations it is somewhere between ten and fourteen years. If the equipment really does last twenty to thirty years, as it's supposed to, that's reasonably good economics.

There's a lot more credibility for the industry. We learned a lot about how to do preparation, homework and gather solid knowledge for a hearing.

In summary, I am going to say something somewhat open to dispute. At the present time, the total installed power of WECS in Canada, under 50 kilowatts, I believe is probably greater in total power than the sum of all other, greater than 50 kilowatt units, in Canada. It must be very close to it, if it doesn't exceed it. These numbers represent the groundswell in support for wind energy in this country. It also represents the groundswell in support for this industry, which we all represent whether small machines or large. I believe that this is an important market in Canada. It is important because it matches very well the loads between the wind energy resources and the users all at the same place.

This ERCB decision affects the small power users in particular, whether in Alberta or in other parts of Canada. This also affects that segment of the industry which relates to that market. With the formation of CANWEA, I certainly hope that the CANWEA Board will take pains to highlight this segment of the industry and users to a great extent when they consider lobbying, policies, objectives, and recommendations.

We've brought some copies of the ERCB decision which you can obtain from David or myself afterwards. We'd be glad to hand them out. There is a limited number though. We'd be glad to discuss these topics in private if you don't want to ask questions out loud afterwards.

For my last statement, I want to point out that although this is a sunset on a windmill, that's certainly not the case for the industry. Thank you very much.

Q. Banks usually charge for services. Did TransAlta charge Ernie Sinnott for providing a banking facility?

A. (Edworthy) No.

Q. So it's just free storage?

A. (Miller) They didn't use the term 'storage', but I don't know what else it is. It sounds like storage of kilowatt-hours. They called it "the banking concept". It's more than just storage, I guess. It's putting the credit in and drawing on it. We went through a hearing process with some disagreement - that was why the hearing was called.

The directive was that the banking concept would be instituted for five years. The Board did identify in the decision that there probably is a cost of banking. There probably is a cost of this service, but again it's difficult to determine what that is, so in the monitoring period, that is another item that we will have to address. Now, whether that's in the annual reports which we have to submit or the five-year report at the end of the trial period, we will address that and indicate what the coast of that banking is. But, during the interim period, there is no cost handed down to the small power producer.

Q. Would it be open for several farmers to join together and install, say, a 50 kW machine rather than 5 individual 10 kW machines?

A. (Miller) Under this concept in, again, one unit you are referring to I guess? Yes. You have the problem. I guess it's vague in some areas in that it doesn't really indicate where this unit should be, but from what I gather, from the decision, it would seem to indicate that the unit must be on the owner's premises. They limited the size to 100 kilowatts per unit and that it should be on the owner's premises, in other words.

It did not encourage, as I mentioned, the concept of wind farming or wheeling of electricity. So, in that case, I don't think that would really fall under the decision. Now they could certainly either be open to other approaches, if that one came up, or a wind farm approach came up. I think they, again, would have to deal with that. It's probably a separate issue.

Q. Alternatively, banks usually pay interest on what you keep in them. Is that built into the $0.016 per kilowatt-hour TransAlta pays back to Ernie Sinnott?

A. (Miller) I think you could take this banking concept a little too far. That's why we'd prefer they called it storage rather than banking. That way we could charge for storage instead of paying interest for banking.

Q. Well, I guess the thing that I am trying to say is, does TransAlta consider this power that they are getting desireable, or do they consider it sort of parasitic in a way? You are doing this because public opinion requires you to do it?

A. (Miller) No, we are doing it because we went through a hearing process and are abiding by a decision. You know, it's essentially, it's a law for five years. That's essentially been the decision, so we are abiding by it.

It's the banking concept, you know, that is a benefit to the small power producer. It disregards time of day, generation, or sale of power. Our industry is based on time of day and demand. This allows a small power producer to bank or store his energy regardless of time of day. In fact, in a lot of cases what will probably happen is he will generate off-peak and draw a lot of that on-peak, so it's already to his benefit. The winds may blow on-peak, but the peak is not that long a period.

Q. If there is a lot of, say, electrical space heating, then during the windy periods, especially in winter, wouldn't that be when you would also draw the electricity? So wouldn't it regulate itself a bit that way?

A. (Miller) Jason's itching to get at the mike here! But, let me just say that, first of all, there is virtualy no electric space heating in Alberta. There is a very small portion of electric hot water heating because they give away the gas in that province. We are hoping to combat that! So, you know, that really doesn't affect it.

A. (Edworthy) The Sinnott installation is kind of unique among SPP's because he has a large surplus which is really part of why this came about. Most SPP's in Alberta have their generation facilities matched very well to their load, so the buy back and the amount of credit they bank is not a significant amount. It's certainly convenient for them because they don't have to try to exploit their generator quite so carefully when the wind is blowing. Without that, you get into scenarios like we presented in Energex where you could potentially get up at three in the morning to use the electricity. With banking you certainly don't have to worry about this. It's very convenient, it becomes more automatic.

In this particular case, he has a very large surplus. As Dave pointed out, he only used 6000 kilowatt hours of the 31,000 he produced. That makes a significant difference to him until he expands his facilities. One of the things that we hope will come out of monitoring this is enhanced 'time of day' information. We will be getting a better picture of how the correlation between peak generation and peak use comes. The Chinook wind is not something that we count on for generation. It does tend to be windier in March and April in this region, and it does tend to be windier in the afternoon, from our monitoring. We'll just have to wait and see how well that comes out. David?

Q. The SPP feeds surplus energy to the grid. I assume that the electricity goes to the nearest other load, such as next door. In Alberta, where are most of the utilities' generating plants and where are the major load sources? Are there big distances between the two? My understanding is that coal plants are up north and most of the users are down south. And after that, I have another question about the site applications in Alberta. Would you say what the pay-back will be on that Bergey installation?

A. (Edworthy) For the first question, at the hearing there was a lot of discussion about transmission losses, what they might be. Certainly most of the generation facility is quite distant from this site. It's almost an academic question where the electricity goes, I suppose, because it does feed on to the general grid.

There was a lot of discussion at the hearing and the decision didn't come to any resolution about that, except to suggest that monitoring and study was going to be required.

A. (Miller) I think he asked also about the location of the load in Alberta. One answer would be that the largest city in Alberta is Edmonton, 40 miles from our major generating plants. The second largest is Calgary, a close second, two hundred miles to the south. The best regime is a hundred miles south of that again. That's very, very crudely described as to where it is. It starts I guess from Calgary south. Does that answer your question?

If this is the road you are leading us down here, there is a component of losses in that 1.6 cents already. The total cost of electricity in Alberta is, as any place, made up of a number of components and fuel is a very small component of it in Alberta. The fuel cost on TransAlta's system, which is mainly coal, is less than a cent per kilowatt-hour. When you look at the total system, which has some gas-fired units used for peaking and some small hydro, that brings it up over a cent. Then there's a loss factor put in there as well, for transmission losses.

A. (Edworthy) You did ask a second question about the pay-back on that Bergey remote unit. As you are probably aware, pay-backs on remote units are always relative to what you'd use otherwise. Without divulging figures proprietary to TransAlta, I think it's fair to say that if one were to bring utility lines into a remote site like that it would have cost more. On that basis, the pay-back was last Friday when it was turned on compared to diesel operating costs. Certainly, there's a back-up diesel at the site. Capital costs for diesel are quite small, operating and maintenance costs at a remote site are quite high. I think some operations will be required to firm that up but it's probably at most only a few years, from my opinion.

Q. So it is competitive to do that in Alberta at remote sites?

A. (Miller) Certainly was. We wouldn't do anything unless it was. We don't do anything that's not competitive.

Q. Jason, you quote some pay-backs that seem pretty decent. What are they based on?

A. (Edworthy) The commercial pay-back is based on work we did that was presented at Energex in the spring. It's basically a cash flow computer programme for a business situation. I have to admit, it does assume Class 34 depreciation. We had a ruling from Revenue Canada in Calgary that it would work. Based on Jay's comments this morning we are going to have to go back and look at that again.

If a business buys a piece of machinery and:

- depreciates it at 50 per cent a year,
- it's well-matched to it's load
- it's in a good wind regime,

and - assuming that they have income against which they can depreciate,

the investment cash flow should be negative only for the first five to seven years. You can carry losses up to five years forward and two years back which can help, mostly on avoiding utility energy purchases, not on selling any back or surplussing. It's just a simple cash flow analysis. They put out the money which they depreciate at a fast rate. They make their own energy so they aren't paying out to the utility.

For the residential one it's the same thing except:

- the tax advantages

and - expenses for interest and maintenance

are not deductible as a business expense. All of those are under a business. That is why the pay-backs at the very best, in a high wind site are more like, probably, eight years. For utility-connected residential, typically around Calgary and north, probably 14 years. Anything longer than that usually isn't a viable utility-connected wind energy site.

You've got to pass on the costs of those ---------------- when you go through the ----------------won't let you pass them on.

CANADIAN STANDARDS ASSOCIATION
SMALL WIND ENERGY CONVERSION SYSTEMS
STANDARDS COMMITTEES PANEL

CANADIAN STANDARDS ASSOCIATION
SMALL WIND ENERGY CONVERSION SYSTEMS
STANDARDS COMMITTEES PANEL

Bill Porter, Panel Chairman
Standards Administrator, Canadian Standards Association

For those of you not already familiar with the mandate of CSA, I have circulated a small brochure entitled "CSA Today". This briefly summarizes what CSA is, who controls it, who are the members, what is a Standard, who pays to develop the Standards, who writes the Standards and what is CSA certification. I think most of you are already familiar with CSA, but if you have any questions, please do not hesitate to ask now or call me at your convenience.

As the Standards Administrator for the WECS programme, it is my duty to administer the funding of our sponsor, the National Research Council, and to expedite the development of the wind energy conversion Standards. It will also be my responsibility to continually monitor the needs of the industry with respect to these Standards; to continually attempt to update and improve the existing Standards, and to undertake new Standards as required.

To achieve these objectives, our primary responsibility is to the CSA Standards Steering Committee on Solar and Wind Energy. As you can see on the screen (figure 1), the Steering Committees are appointed by the Standards Policy Board. In the development of consensus Standards, it is the policy of CSA to seek representation from all interested parties, such as regulatory authorities, owners, users, and general interest groups, including consumer representatives.

The Steering Committee for the Solar and Wind Energy is presently under the Chairmanship of Mr. Robert Aldwinkle, Director, Solar Programme, National REsearch Council. The CSA Technical Committee, for the wind Standards, is under the Chairmanship of Malcolm Lodge, who needs no introduction here. As the following panel speakers will indicate this afternoon, we are not too far from publication of initial wind energy Standards. It is our purpose today to bring you up to date on the progress of each of these Standards.

The decision to publish each Standard is basically that of the Technical Committee. On their two-thirds favourable ballot, we may publish a printed "Preliminary Standard". Should the Technical Committee have confidence in the work of their sub-committees, and their own review, they could decide to publish the formal Standard, which would then require a second level ballot of the Steering Committee with 60% approval.

Since the focus is now on the Technical Committee, the Committee Chairman has kindly agreed to review the background, the progress, and the future plans of his capable team; and also to

Figure 1: CANADIAN STANDARDS ASSOCIATION
As related to Solar and Wind Energy Standards

Canadian Standards Association

A voluntary national organization made up of business. Government. labour. consumers and associations.

Standards Policy Board

30 members appointed by and responsible to the CSA Board of Directors made up of a balance of producer. user, Regulatory Authority and general interest groups.

Standards Steering Committee on Solar and Wind Energy

Established by the Standards Policy Board. Membership to have a reasonable balance from producer, user, Regulatory Authority and general interest groups from both Solar and Wind Energy Communities. Usually includes Technical Committee Chairman.

TECHNICAL COMMITTEES

TECH. COMM
WIND ENERGY
CONVERSION
SYSTEMS F381

SOLAR
COLLECTORS
F378

SOLAR HOT
WATER HEATERS
F379

PHOTOVOLTAIC
CELLS
F380

SUB-COMMITTEES

DESIGN CRITERIA

PERFORMANCE (F417)

INTERCONNECTION (F418)

SITING/INSTL'N

SAFETY (F416)

TECHNICAL COMMITTEES - Responsible for the technical content of standards. Established by Steering Committee, the membership should have a similar balance. Usually includes subcommittee chairmen.

SUB-COMMITTEES - Responsible for providing technical knowledge, ideas, and experience towards development of standards. Should reflect a national consensus of producers, users, regulatory authorities and other interests.

introduce his sub-committee Chairmen, who will then individually enlarge on the progress of their individual task forces. Mr.Lodge....

TECHNICAL COMMITTEE - WIND ENERGY CONVERSION SYSTEMS

Malcolm Lodge, Chairman
Resource Ventures Inc.

I'm beginning to think I am going to have to eat this microphone. I will be very glad to leave it at the end of the day.

I missed the introductory remarks that Bill has made. I guess I came in not long after he commenced. The Technical Committee has been active now for almost two years in the process of developing Standards for small wind energy conversion systems in Canada. We grew out of an ad hoc committee that was put together about a year before to try to establish a strategy for the development of wind Standards. One of the early policies that the group adopted was that we would try to make our Standards as compatible with those of our neighbours to the south, the American Wind Energy Association, who had been involved in the development of Standards through funding that they had received through the Department of Energy. Their programme, as a result of interruptions in funding and contracts with DOE, was somewhat on-again off-again but they are now more or less parallel with the efforts that we are making. Although I guess there are no Americans here anymore, I see Norm is gone, we are certainly grateful to them for a lot of information and preliminary concepts that went into the formation of the Standards that our group has developed to date.

The Technical Committee originally conceived that there were about eight areas of wind technology that required Standards. Although I have been Chairman of this Committeee for a few years, sometimes I am still a little bit in doubt about just what the intent and scope sometimes is of some of the Standards.

The major sections of the technology that we felt it was necessary to address, and these were somewhat in keeping with the US experience were, first, the matters of safety: essentially to ensure that the machine and equipment manufactured and sold in Canada does not offer a liability or a risk to the user or to the general public.

The second major area was that of performance, to ensure that a machine, if advertised and rated and certified to deliver a particular level of output of energy per unit of windspeed, that in fact it did that according to some reasonable criteria.

Another area that was of significant concern to us was the matter of electrical interface, which once again reflects on safety, but primarily the electrical interface inasmuch as utilities and other organizations are concerned about the quality of power and the effect on their systems.

The matter of siting: where should wind turbines be placed, where shouldn't they be placed. How do you assess a site, was another matter.

Those four items are matters that have been dealt with and for which sub-comittees have been formed. The gentlemen here with us today are the Chairmen of those respective committees.

Other areas that we have yet to deal with are matters of installation, and even such things as terminology and rating, certification documents, means of rating and certification, matters of controls. These utlimately will all be placed together in one Standard for SWECS. Some of the regulations will be suggested practice and others will be mandatory, or suggested mandatory regulations and guidelines.

We are presently at the stage, and I am not going to take away from our speakers, to give you the current scope and status of the Standards as they have developed them. They will be able to communicate those to you much better than I.

Before we go into the individual sub-committee reports from each of the Sub-Commitee Chairmen, it is once again a pleasure for me to ask Carl Jorgen Christensen from Denmark to give us a brief statement of the Danish experience with Standards and certification programmes and to elaborate to us a little bit the effect it's had on their industry. The desirable effects that he feels it may have had. Maybe also indicate any pitfalls or areas that we should perhaps avoid.

Carl Jorgen has, as you know, and those of you who had the pleasure of listening to his talk yesterday, is the Manager and Head of the Riso laboratory in Denmark for testing small wind energy systems. His laboratory is the model that I look to for many of the things that we are doing at the Atlantic Wind Test Site. I have always felt when I visited his lab that it was a very hospitable and nice place to be, even if I have been there occasionally when something came apart. So it is my pleasure, once again, to introduce you to Carl Jorgen Christensen...

STATUS OF SWECS STANDARDS IN DENMARK

Carl Jorgen Christensen, Riso National Laboratories

Well, thank you, Malcolm. I must start off by saying that I am completely unprepared to stand in on this discussion. If you can hear in what I say that I am unprepared, it has its explanation.

I do think, however, that this discussion is so important that I would like to add a few things about what we are doing along these lines.

We start with what I mentioned yesterday, our licencing work. In doing licencing you have to establish rules for licencing. We have been doing this for many years now. But that, as far as we can see, is not the same as Standards. Therefore, it was decided about one year ago to start real work on Standards. Still, the licencing rules have been the ones that have been important for Danish industry in the way I described yesterday.

The rules we have are barely written down. They are constantly under development. This is one of the reasons they can promote the development of windmills. It allows us regularly to come up with new problems we have seen, let them have their influence on the rules and then put them into effect on industry immediately. This system has worked very well in Denmark, even though it is a funny kind of system. It doesn't really have any legal or other background. It is to a high degree an ad hoc solution. It has always been one of the ideas of the system that we should not hinder development. On the other hand, we should make sure that people do their homework when they construct machines so they are both safe and hopefully pressing in the direction of higher reliability.

I should mention one difference between Denmark and Canada, mainly that we have stopped talking about small wind energy systems, at least at the test station. We have actually changed our name so that now we're just a test station for windmills. A couple of months ago, we have just started licencing procedures for the biggest Danish machines, the next generation WINDANE 40 machines at 750 kilowatts. This is because their financing is from the same source as the regular subsidy and therefore ultimately they belong under the system. Consequently, we are now trying to go through the construction of those machines. So, in principle we cover all sizes.

Now this was our own work as it has been going on hitherto. Next comes the Standard Committee. I have just read through this little folder about the Canadian Standards Association and as far as I can see it is pretty close to the system we have in Denmark. The main difference is that in Denmark this Committee work is coupled to the Danish Engineers Association. This union has been undertaking the establishment of Standards as a normal part of its work for many years.

Apart from that, I think the work aims at the same goals as your Standards organization. This is serving industry users and the Government administration to make things safe. Industry has guidelines to make their work easier and make it go in a decent way. The Danish Engineers Association one year ago set down a working group with the sole goal of establishing windmill Standards.

One other difference is that we are concentrating at the moment only on safety Standards, as that is what the system usually will be working in. It was originally designed for the building industry. As the authorities have a heavy hand in the use of these rules, it's natural that safety must come in as the first priority, whereas I think you are working on a broader basis. So that does make up for some difference.

In this system, a Working Group will write a Standards paper. Next, a Reviewing Committee will be set down. The Working Group has representatives from the wind energy industry, the test station, different research organizations and the utilities with windmills on their grid.

We have not given up the idea of establishing Standards for both small and big machines. We will have to find out as the work progresses whether we can hold this broad scope. Once you get down to the basics, there might be differences between big and small machines, even though we don't think these differences are of a principal nature.

We are only halfway through our work and therefore far from actually having papers like you have here.

I would like to mention, as a last thing, that I do find it very important to establish international cooperation with this setting of Standards. I think it is fairly well-known that the traditional way of stopping international trade is to establish different, conflicting safety rules. This is used to a high degree by many countries when they try to protect their own industry. We at least work very much on trying to get to an understanding between countries on more or less similar Standards. In order to do that we emphasize pretty much the cooperation that exists between the international test stations.

This is not a very formal organization, but by now it is a very real organization. Test stations meet generally once a year to discuss common problems. I think at the moment we have about twenty registered members of this informal organization. I can mention a few of the dominant stations. That is: the USA and Canada represented by AWTS, Denmark with our Riso test station, Germany, Holland, England and to go to the extreme, our newest member is China. So it's a very big organization.

We intend to get discussions going on Standards in this international test station cooperation. We will seek common projects that have been started and run between meetings. We have been lucky enough to induce the Common Market, the EEC to finance some of these projects. Unfortunately, we run into national limits with the EEC saying that as a matter of principle they cannot pay test stations outside the EEC for joining the work. We have been happy enough to see that the prominent stations outside the EEC, namely the US and Canada, have promised that they will join the work and find their own resources to do it. We are very happy that this is possible.

We think it is very important to keep this going. The meetings between the test stations will regularly review what is going on in Standards. I could mention in this connection that the next meeting will be on Prince Edward Island at AWTS in some time around summer of 1985.

MALCOLM LODGE

Thank you very much, Carl Jorgen. And I do hope that those commitments that we made to participate in those projects are possible for us.

PERFORMANCE SUB-COMMITTEE - SMALL WIND ENERGY CONVERSION SYSTEMS

Ray Richards, chairman
National Research Council

We put together a Sub-Committee on Performance Standards about a year and a half ago. The Committee is composed of a number of very dynamic individuals. We tried as best we could to get a good representation of the different interest groups that the CSA requires for such a Sub-Committee. I'd like to introduce these members to you just by reading their names and identifying the particular interest group they have been extracted from. First of all, Professor Terry Base, from the University of Western Ontario is on our committee and represents a researcher in the field of wind energy. Secondly Dave Baker of the Alberta Research Council representing the wind test site for water pumping stations out west. Thirdly we have Robert Kelland of the Colleges of Trades and Technology in Newfoundland, representing again the researcher interests.

In terms of manufacturers we have Brian Richards, no direct relationship I don't think, of Shawinigan Consultants Inc. and Lawrence Schienbein, a Manager of wind energy engineering at DAF-Indal Ltd. Consumer representation was given quite nicely by Victor Wagner, who is here in the front row. And of course myself as Chairman, initially representing a wind test site and later the National Research Council.

Before I get into the index of our performance standard, I think it might be appropriate to review the scope of the standard.

First of all, this particular standard specifies methods for determining and reporting performance characteristics for wind energy conversion systems. This standard applies to WECS having mechanical, electrical or thermal output. This standard is not concerned with noise generated by the WECS except to report the overall noise level and the procedure used to measure that noise level. The standard does not address issues of reliability, safety or durability except with specific reference to performance. The standard is not concerned with the siting or installation of a WECS and it is not concerned with the electro-magnetic interference that may result from the use of a wind turbine.

Now that I have covered the scope it might be appropriate then to look at the index of the standard. This is the index of the preliminary draft standard which has yet to be ratified by the technical committee. The first go-round is due for tomorrow at which time the Technical Committee will either decline or accept the preliminary draft standard as it exists now.

I've outlined the scope, which is section one.

Definitions, section two, we found to be an extremely important aspect of the standard, as I imagine it is for all the other standards. Without proper definitions you cant't logically and intelligently discuss any standard. Consequently, it is an extremely important aspect of standards development.

Skipping to section 5, the field test method describes essentially the installation and specification of instrumentation for each of the various parameters that are measured in the field test. For example:

- the windspeed
- the anemometer in Section 5.4.1.
- its location and power monitoring, Section 5.5,
- Temperature Monitoring, Section 5.6

and - Atmospheric Pressure Monitoring in Section 5.7.

The majority of our time in the development of the standard was spent on Section 6 which identified the procedure used to determine the performance curve of a WECS in the real wind. In particular, Section 6.4.1, the 'method of bins'. This method was borrowed essentially from the AWEA and IEA standards which were in existence at the time that the CSA standard was considered. Both of these standards provide an excellent foundation on which to build the CSA standard. In many respects they helped rid us of the task of building some of the more minor aspects of the standard. This allowed us to concentrate the majority of our time on the meat of the standard, which is really the procedure to measure the performance curve.

It also gives us an opportunity to look at other methods that can be used to establish a performance curve. In particular: the running average method, the method of most probable power and the energy method which have all been described at one time or another in the literature.

However the 'method of bins' was considered to be the most appropriate method for our investigation because of its popularity. As it turned out, through some of our own computer simulations and other investigations, we found it to be as good as any method.

No one particular method that was investigated turned out to be more appropriate than another in terms of user-friendliness or in terms of the accuracy of the prediction of the performance curve. So, no particular preference was given to any one method based on that criterion, however since the 'method of bins' has been around for quite a few years, and is in popular use, the CSA standard decided to adopt that particular method.

Because we have the IEA and AWEA standards to build on, we looked at some of what we felt were shortcomings of both standards. We identified a few areas.

First of all, there seemed to be no consistency in determining minimium data base requirements. We looked at this question for quite some time and finally decided on the method of defining a confidence interval on the data within each bin. This I described yesterday in my presentation.

We looked at possible corrections to the performance curve due to turbulence effects and non-linearities in the performance curve of the turbine. However, since we had no real, hard experimental data to support the theoretical considerations, we opted not to include them in the standard at this time. Nevertheless, we are looking into this problem in more detail in the coming months.

Another thing we looked at was the averaging interval used for the data. The AWEA standard recommends the use of one minute averages, whereas the IEA standard recommends the use of 10 minute averages. Our investigations showed that it doesn't really matter. Just about any averaging interval between those two limits is satisfactory. In the end we opted for the ten minute average, in keeping with the International Meteorological Standard, and that was basically the only reason we adopted that for the averaging time.

There were also some considerations with respect to air density corrections that are performed in both AWEA and IEA standards. These create some problems, particularly with respect to cut-in windspeed for a turbine.

If one applies the adjustments that are recommended in the IEA or AWEA standard to power measurements, one finds that you can overpredict the maximum power or the installed power of the turbine just through the corrections to standard conditions.

Also by shifting the power curve vertically you can change the cut-in windspeed of the turbine. The cut-in windspeed can only be correctly accounted for by adjusting or correcting the performance curve with respect to the dynamic pressure on the blades at cut-in. This is something that we are presently looking at. We hope to include it in the revised version of the preliminary draft standard which we have produced to this date.

Basically I've covered: the general scope of the standard, the areas that we've looked into, the differences between the standards. I think that we've come up with a standard that combines the best of the existing standards, the IEA and AWEA standards, and extends the standards a little further.

I guess that's really all I have to say and I can turn the podium over to the next speaker.

Q. I am wondering who the standard is aimed at. Are you expecting the manufacturer to use this standard to say what the performance is or are you aiming it at essentially a national test centre? Who is going to be the one to use the standard?

A. We hope that both groups will use the standard. The manufacturer will be aware of the standard to which his machine will be tested and can make the necessary design changes and implement the necessary structural features that are needed to meet those standards that a wind test site would be using.

Q. It wouldn't be up to the manufacturer, or the CSA wouldn't adopt the manufacturer's performance results? The CSA would go to another body for the measurement?

A. (Richards) That would be the most likely scenario. But I don't think it would be beyond the realm of possibility for the CSA to have a close look at what the manufacturer had to offer in terms of performance measurements and apply that to the standards as a yardstick.

A. (Lodge) If I could interject the policy with respect to the example of the American Wind Energy Association standard development? The industry there insisted that the standard be written in such a way that the provision be made that the manufacturer with reasonable ease could measure the performance of his own wind turbine to that standard, whether or not his measurement was accepted by the under-writing agency is another question. Bill, did I see you jump to your feet there?

A. (Porter) I think this question of rating and certification is probably the next phase, after we complete these initial sets of standards, - if that answers your question.

HIGHLIGHTS OF THE PROPOSED
SMALL WIND ENERGY CONVERSION SYSTEM (SWECS)
Safety, Design and Operation Criteria
(CSA Standard F416)

R.S. Rangi, Chairman,
SWECS, Safety Subcommittee
(National Research Council, Ottawa, Canada)

Presented at:
Seventh Annual Wind Energy Symposium,
December 10th and 11th, 1984,
Harbour Castle Hilton, Toronto, Canada

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2. Scope
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1. Introduction

The increasing use of Wind Energy Conversion Systems (WECS) as a source of supplementing individual and national energy needs requires that safety, design, and operation criteria be provided to assist in their successful development and use. These criteria were developed by consensus input using national and international participants. The proposed standard, while addressing the international criteria, also covers the specific requirements to meet conditions within the Canadian environment. This paper gives a brief outline of the proposed standard.

The purpose of the standard is to specify design criteria for safety of Small Wind Energy Conversion Systems (SWECS) with rated mechanical power of 100 kW or less. These criteria apply to all types of machines (horizontal or vertical axis), that may convert the kinetic energy flux of the wind into electrical, mechanical, or thermal power.

Particular attention is paid to features of the wind regime and ranges of design values appropriate to North America. The various modes of WECS operation and non-operation involving a different mix of environmental and loading parameters are also addressed.

This Standard was prepared by the Subcommittee on Safety of Small

Wind Energy Conversion Systems under the jurisdiction of the Technical Committee on Wind Energy Conversion Systems, and the Standards Steering Committee on Solar and Wind Energy and was formally approved by these committees.

2.0 Scope

2.1 This Standard is concerned with the safety of Wind Energy Conversion Systems, including design and operation under specified environmental conditions.

2.2 This Standard is concerned with systems of 100 kW or less of rated power, mechanical, electrical or thermal.

2.3 This Standard is concerned with all sub-systems of SWECS including Protection Mechanisms, Supporting Structure and Foundation.

2.4 This Standard is concerned with the components and materials supplied by the manufacturers, with the adequacy of the assembly, installation, maintenance and operation instructions, and with the safety of the system after assembly according to those instructions.

2.5 This Standard is not concerned with siting of SWECS, utility requirements for interconnection to the power grid, SWECS performance, or effects of SWECS on the environment.

2.6 Compliance with this Standard does not relieve any person from the responsibility of observing applicable local, provincial and federal regulations.

2.7 This Standard covers minimum requirements and is not intended for use as a complete design specification or instruction manual.

3.0 General Requirements

3.1 Rotor and support system conforming to this Standard must be safe life designed.

3.2 SWECS Controls and Protection Systems must be designed for fail-safe operation such that in the event of failure of a component, the machine will remain in a non-hazardous condition.

3.3 SWECS conforming to this standard must be designed such that maintenance can be safely carried out by following instructions given in the SWECS manual.

3.4 A SWECS manual, appropriate to the particular machine, shall be provided by the manufacturer, The SWECS manual must contain information on erection, inspection, maintenance procedures, and special tooling. A specific sequence of procedures to commission a new or repaired SWECS must be prescribed. Detailed procedures must be given to check proper function of safety, protection systems and trouble shooting routines.

3.5 In addition to this Standard, SWECS located in severe environmental areas shall be evaluated against special criteria dictated by the site.

3.6 The procedures used to manufacture, transport and erect the SWECS shall consider loads, deformation and exposure to the environment of the components and assemblies.

4.0 Environmental Conditions

The following minimum Environmental Design requirements are specified in the Standard:

a) Survival Wind Speed
b) Wind Shear
c) Wind Gust Model
d) Wind Directionality
e) Temperature and Humidity
f) Icing
g) Lightning
h) Earthquakes
i) Hail

Normal environmental conditions generally concern long-term system loadings and operating conditions. They need not represent the critical design conditions.

To ensure safe machine operation, a SWECS shall be designed to remain operable following those extreme environmental conditions which are rare but real. A 100-year recurrence interval for determining worst case environmental conditions is considered adequate.

5.0 Design Considerations

5.1 Design Load Cases

The following load cases account for the various operating and non-operating modes for which a SWECS shall be designed. Sound engineering analysis of these cases will require appropriate aerodynamic and structural models. Care should be taken in understanding the SWECS status in each case (operating or shutdown), and dynamic factors should be applied in excess of calculated static loads where appropriate.

The following load cases are considered appropriate:

a) Dead load of all supported elements.
b) Survival wind loading as per section 4 on all exposed surfaces and calculated consistent with National Building Code and CSA-S37M.
c) Ice coating on all exposed surfaces to recommended coating thickness.
d) Static and cyclic loads transmitted from the rotor during normal operation at rated power, and wind loads on other components at operating speed.
e) Loads associated with overspeed of 10% greater than the maximum controlled overspeed allowed by the protective control system, on rotor and on other components.
f) Maximum static and cyclic loading in 3 second gust conditions while in operation.
g) Loads experienced during normal starts and stops.
h) Loads due to braking, feathering and furling, etc. experienced during emergency shutdown.
i) Loads experienced during transportation, handling, erection and servicing operations.
j) Seismic Loading

The above load cases (a) to (j) are all specified (or service) loads.

5.2 Loading Combinations

The design of the SWECS rotor and the support structure shall consider the following combinations of loads (defined in 5.1).

i)	= a + d	Rated Power
ii)	= a + d + g	Normal starts and stops at rated power
iii)	= a + b	Survival wind
iv)	= a + 0.5 b + c	Full ice load and wind (wind loads based on the iced sizes of members).
v)	= a + e + f	Overspeed and gust
vi)	= a + e + h	Overspeed and emergency shutdown
vii)	= a + d + f + h	Rated Power + gust + emergency shutdown
viii)	= a + d + j	Rated Power and seismic loading

Sound design practice shall require that loading cases be applied over the design safe operating life of the SWECS. Combined load case analyses shall include appropriate loading recurrance intervals.

Cyclic or frequent loads shall be considered to act over the intended life of the SWECS and used for the fatigue life design. Design for all other loads that act once only may be made using "allowable stress" or "limit states" methods.

6. Component Design

6.1 Rotor and Support Structure

This section outlines the minimum design requirements for the rotor, the support structure, anchorage and the foundations.

6.2 Electrical Systems

This section applies to SWECS used for generation of electricity including the following uses:

Battery charging
Supply of electricity to power conservation equipment (e.g. inverters, motor generators)
Feeding load (e.g. resistance heating)
Utility grid connection

7. Tests and Reporting

Each SWECS model shall undergo shop tests and 6 months of testing to ensure a sound structural design, a vibration free machine and safe operation of control and emergency subsystems.

The test shall include simulated fault conditions to test the control and protection system. The test period shall also include representative weather conditions.

The test program must be documented and the report shall follow guidelines established in the Performance Standard.

SITING SUB-COMMITTEE - SMALL WIND ENERGY CONVERSION SYSTEMS

Donald McKay, Chairman,
Atmospheric Environment Service

The other two gentlemen that spoke were describing standards which to me mean: 'the things that thou shalt do in order to build a WECS'. The task given to our Sub-Committee, which at the present time, is a total of one, myself; was to look at guidelines as opposed to standards. We feel that, with regard to siting, we cannot really dictate what people should do. But we should certainly, hopefully, give them some advice and guidance on what they should not do when they are looking at trying to evaluate particular sites for siting WECS.

The title of the work that I am doing is: 'Guidelines for Siting of WECS'.

The purpose is to provide a set of procedures and methods which one can use as guidelines for evaluating a site where one is proposing to put a WECS. I felt initially before trying to produce these guidelines by committee it would be appropriate to sit down and review the literature. I wanted to see what people had written on the subject, what is available, some of the common sense ideas, and just talk to people. I could then come up with a document which could be reviewed by the Technical Committee and other people that we felt should have some input. Hopefully, this will result in a useful initial document telling people what to do and what not to do when they are looking at a wind site.

The present table of contents (Table 1) is similar to what other sub-committees have developed.

We looked at a scope. What's it all about? Why are we doing it? What does it entail?

The next is what's the significance of it? How can it be used? What are we trying to get across?

Next, as the other two speakers mentioned, terms and definitions. What are we calling things. What is meant by various terms. We find that different people have different ideas on what certain things mean.

Then, getting into more of the meat of the document, we looked at the procedure.

Firstly, we looked at what a site evaluation was. From that point of view, I looked at what sort of data would be required depending upon what type of system you are putting up. I based it on the idea that it is something smaller than 100 kilowatts as with the rest of the SWECS standards. You may have a different idea of how you are going to do a site evaluation if you are putting up a very small machine. Whether you are just an

Figure: 1

CONTENTS

1. Scope

2. Significance and Use

3. Terms and Definitions

4. Procedure
   i. Site Evaluation
   ii. Wind Measurement Systems
   iii. Accuracy and Reliability
   iv. Wind Energy Site Characteristics
   v. Installation of Measurement Systems

5. Reports

6. Environmental Hazards

individual consumer wanting to put one at your cottage, compared to somebody who may be going in for a larger more elaborate machine. So, what sort of information do you want to look at? That's what the site evaluation is.

Then I looked at various wind measurement systems. How elaborate does one want to get. What needs to be done and what sort of systems are available? I didn't go into naming systems as such, but more into the various classes and types of wind measurement systems that one would want to look at.

I had a section on the accuracy and reliablility, depending on how I had divided these various wind measurement systems. They do have very different accuracy and reliability! I thought it would be necessary to give some guidance in that area as well: what people should be doing and what they should be looking at.

The next area which seems to be the real important area is the wind site characteristics. What should one be looking for? What should one be concerned with? I drew most of the information there from two documents:

- Taylor, P. A. and Lee, R. J., 1984, Simple Guidelines for Estimating Wind Speed Variations Due to Small Scale Topographic Features, Climatological Bulletin, vol. 18, no. 2, pages 3-32.

- Wegley, H. L. et al, 1980, A Siting Handbook for Small Wind Energy Conversion Systems, PNL-2521 review .1, Pacific Northwest Laboratories, Richland, WA., U.S.A. 99352.

In section 4, Wind Energy Site Characteristics, I've tried to list some of the things that one should look for in siting a wind turbine. I've also listed some of the things to avoid, such as not putting it too close to buildings, and being outside the turbulence layer and things along that line.

In section 5, the Installation of Measurement Systems, I felt there was the need, again, for some guidance. If one is going to go into a monitoring system: to monitor the site; to have a look at how one should install the WECS, one needs to know how to record the information and document it. So, some quality controls and things like that are discussed.

Further on in section 5 is the Reporting Mechanism. If one is going to go to the trouble of monitoring a site, they should have some systematic way of how to look at it and what type of reports should be made available. So the idea was to give some guidance along these lines.

Under that procedure Number 4, all except the 'IV' in there was pretty well taken from the AWEA guidance material that was put out. As Malcolm mentioned at the beginning, we tried to be in step with them and follow along. Initially, I took a lot of the material that was produced by AWEA and incorporated it into this report, except for 'IV'. For the wind energy site characteristics, I took most of the theory, or a lot of the material, from the two documents that I previously mentioned.

The final area for guidance concerns: 'what are some of the environmental hazards'? What sort of things should one look out for? For example, turbulence. What about severe weather such as tornados or thunderstorms or lightning? What about problems such as sea spray and blowing dust? So I mention and talk about these things and what people should avoid.

Where am I at presently with the document? Well, as the other two gentlemen mentioned, tomorrow I'll be presenting to the Technical Committee my second draft. I had an initial draft which the Technical Committee reviewed. They provided some very good advice which I've incorporated and to which I've added a bit more. I will be passing this along to the Technical Committee tomorrow to have a look at. Hopefully, the members of that committee will then forward it onto other people of interest in order to get their input as well.

I'll just end there on what I'm doing in regards to the development of siting guidelines.

Q. I'm not sure if it is a question on siting or a question on safety. Was it the intention to put anything in the standards about how far you can throw blades, or how far away from other things should one be? Not from the point of view of being sheltered from the wind, but just from a safe point of view?

A. (McKay) To answer that question, in the siting document that has not been covered. But, I believe there has been a little bit in the safety, has there not, Raj?

A. (Rangi) We did discuss it Jack, but did not specify any throw distances, we just assumed that due to safe life design of the rotor there wouldn't be any blades thrown. This assumption is not quite true as we all know there will be times when rotor failures will occur.

> (Editor's Note: Danish Ministry of Energy report #EEV 81-01E notes 'blade-throw' to a maximum of 700 meters, but this small country will allow large wind turbines within 300 meters of built-up areas.)

A. (Lodge) If I may, Jack, one of the areas that we haven't dealt with yet that is a potential standard area, is the installation standard and I am not sure whether we will pick that up or not, but certainly that is something to be considered. We all know that there have been wind turbines put in places where they shouldn't have been put.

INTERCONNECTION SUB-COMMITTEE
SMALL WIND ENERGY CONVERSION SYSTEMS

Jim Lea, Chairman,
The Maritime Electric Company Limited

I know the hour is late, so I will try to be brief. I know people have things to do and are anxious to get going. I don't, however, wear a watch, so if I go for too long, Malcolm you can gong me.

The purpose of our standard is to try to define how the overall interconnection system with the utility should perform. How it should perform with respect primarily to safety. In other words, as Raj just mentioned, systems, although they are designed to withstand all the conditions to which they are subjected, sometimes fail. The purpose of our standard is to ensure that when this happens the interconnection system will operate properly so that the systems are safely disconnected from one another, that there is no hazard to personnel and things of that nature.

We have attempted, and I hope successfully, to coordinate this standard with the other standards that are being developed in this area. We wish to make sure that there is no duplication and that the overlaps are limited and smooth.

The makeup of the panel I will just summarize, in the interests of brevity. They can wait until the standard is published to receive their acclaim, or blame, whatever it may be. It consists of 13 people, two from government, six from utilities, two from manufacturers, two CSA advisors and one consumers' representative.

We began in June of 1983 and have been meeting approximately every two months. As a starting point we did have one or two documents to begin from. We had an AWEA guide which was in draft form at that point. We used it to a certain extent, but primarily, however, we built this standard up from scratch.

The present status of the standard is that it is in draft form. It is not yet ready for presentation to the Technical Committee, but we expect in the next few months we will be in that position.

I'll just run through the index and highlight the areas where we felt we had particular concerns and had spent some time on.

With regard to the scope.

The scope of the standard is to define the performance of interconnections with utility systems. It encompasses all the components used together in a manner that is supposed to operate to feed into a utility system. The standard addresses the safety questions and the capability of the interconnection components to meet the safety requirements. It does not apply to procedures although we will be issuing notes in an appendix where there will be some references made. Each jurisdiction of course, each utility or authority having jurisdiction in various areas, has various regulations and procedures which they will probably have in effect for anyone wanting to make an interconnection. We have tried within the standard to avoid building in wording that will be in conflict with any regulatory jurisdiction. We've tried to make the standard sufficiently broad that it will be able to encompass any of these regulations.

At this point we haven't set a size limit either to our standard. Originally, we began with the idea that it would apply to interconnected systems of up to 500 kilowatts. But then we felt that since we had no specific reason for setting that point, we would wait until the standard was completed to see if there was any part of it that dictated a maximum size. To this date, we haven't set one and there doesn't appear, at this point, to be any reason to do so.

At this point also, we have not put anything in the standard which necessarily makes the standard specific to wind generated systems. It may come in the end, but at this point there is nothing.

The standard doesn't address the details such as metering and generation techniques.

The general requirements are the section of the standard in which we include everything we can't fit in anywhere else and they are not yet complete.

With respect to customer requirements, Section 4, this section indicates what information customers have to make available to the utility or the regulatory authority having jurisdiction. The information consists of things such as:

- a one line diagram,
- a description of the normal and failure — modes of operation of the system,
- a table of the electrical characterisitics of the system including:
  - the type of generator,
  - the rating of the maximum output in kilowatts,
  - the voltage,
  - the current rating,
  - the power factor ratings at various

load levels,
- a performance curve of power output versus wind
- the expected energy production,
- in-rush current
- start current

and - the number of phases.

As well, there will be requirements for information on:

- the fault current label in the machine,
- relay or protection system characteristics,

and - the setting information is required too.

Customers will be required to make notification of any modifications of systems, prior to making any modifications.

Section 5, involves the utility performance. The utility is obliged to provide certain amounts of data to the customers as well. This includes such things as:

- the maximum and minimum fault values at the selected site,
- the various fault sequence impedances and things of that nature.

(These are details that the customer requires in order to set his protection systems).

- the settings of the protection systems on the utility's distribution or transmission system
- as well as some indication of expected transients, for example, over-voltages.

As well, before energization there is a clause in there that says the system shall be approved by the utility and/or the authority having jurisdiction.

Section 6, Operating Requirements.

This is the section which indicates how the thing is supposed to perform under various conditions.

For example, the system shall be so designed as to not be capable of energizing the utility system after an outage has occurred on the utility system.

With regard to system start-up, safety and stability, the parallel generating system shall be equipped with a suitable control mechanism which will permit safe connection to the system. If the utility system is to be energized on the utility side of the switch, the WECS shall not interconnect until a specified time period has elapsed during which the utility system has been continuously energized. Exact procedures shall be agreed in writing between the utilty and the customer. Capacitors shall be de-energized when out of service.

Section 7, Equipment Requirements.

This section indicates that all components of the interconnection system equipment shall meet CSA Standards C22.1. This section specifies various components which must be in the system.

It doesn't say, for example, you must have two or three different switches, it just says the system has to be capable of doing this. It is left to the designer of the system to determine how many of the various switches, fuses or breakers, or whatever combinations he requires.

There has to be a primary disconnecting means. This is a safety-related item. It has to be such that it is manually operable. When it is open, its open state must be positively verified by an observer. It must be capable of being locked and tagged in the open position. There are requirements for grounding the DC stage in a system with isolation transformers in it.

Section 7.4, Fault Protection.

This section requires that the system be capable of an automatic response to internal or external faults. Internal faults are defined as faults within the customer's own equipment. External faults are faults within the utility system. The fault protection system has to coordinate with the utility system. For a utility system fault, it shall isolate the system before any utility re-closing cycles occur.

This was a particularly difficult section for us to deal with. Some of these re-closing intervals can be extremely fast, one or two cycles on some of the modern recloses that are used in utility distribution systems.

It defines the required and suggested protection systems. Phase overcurrent protection on each individual phase is required. Over and under voltage protection is required. There is a list of other protection items which the standard says may be advisable. These are not specified because the requirements will depend to a large extent on the size of the installation. A very small installation will obviously have a very simple and straight-forward protection scheme. A large system will be able to justify more complexity and require a more complicated system.

Section 8, Performance Requirements.

Section 8.1, Utility System Transients. This section defines what the interconnection system shall be capable of operating under, what sort of transients coming from the utility system, the interconnection system will have to withstand. There is presently no Canadian standard which addresses the question of transients in the utility power systems. I believe there is some work, very preliminary work being done now but to date there is no standard. We have elected to quote a standard, an IEEE standard, called the 'Guide for Surge Voltages in Low Voltage A.C. Systems', IEEE Standard C62.41. It's a standard which really just lists various transients which can be expected in low voltage systems. Our standard specifies that the interconnection system must be capable of withstanding the transients defined in the IEEE standard.

Section 8.2, Voltage Specifications.

This is a straight-forward section. The system must operate within the limits of the voltages defined in CSA standard C-235.

It also addresses phase unbalance. The maximum phase unbalance is 5 per cent.

At this point, the standard says that the power factor shall produce rated kilovars. If it consumes vars, a power factor correction may be required.

Harmonics?

We've had an awful lot of trouble trying to define performance of the system with respect to both harmonics and flicker, as well telephone interference. As a result, we feel that both these items are very site specific. In other words, the extent to which harmonics will influence the system is dependent on where in the utility system the interconnection is located. The same holds true with flicker. Utilities have varying regulations for the flicker which is generated from a customer's equipment. As such, at this point, we feel we can't include a statement on maximum harmonic output because there is no way to effectively say what is permissible. Under certain conditions certain amounts of harmonics can be permitted. Under others, they wouldn't be allowed. So harmonics, flicker and telephone interference will all be addressed by saying that they have to be worked out with the utility. They are based on site specific information which has to be addressed at the time of interconnection.

That's very briefly the contents of the standard.

Q. I'm thinking particularly of the situation where you have a fixed blade machine with an induction generator, like an Enertech. What happens for obeying the relationship to the safety standard when the utility disconnects? The windmill will then be in a runaway condition. Has there been any collaboration between the two sub-committees on this?

A. The standard says that if there is a fault in the utility system, or the utility system is off, the interconnection system has to be designed so as to safely shut down the windmill. Also, it addresses the question of re-energization of the system and resynchronization. I think Malcolm had suggested some comments on it. Right now the standard says that re-synchronization can occur automatically after the utility system is restored and within, I believe, a five minute time interval.

But with regard to your specific question, the standard says that the system must be designed such that the windmill will shut down automatically and safely. In our standard, yes.

Q. I'm not sure where the origin of that previous question is, because those Enertech windmills have that designed in for all their models.

A. (Lodge) Victor, there's a question coming back at you there.

Q. I don't know. I didn't know that they had a brake on them.

A. (Lodge) There's a full service brake on the Enertech.

Q. There are hydraulic ones and mechanical ones. The only reason they've ever been allowed into Alberta and many other places in the States, is that they disconnect and shut down within three revolutions or less.

MALCOLM LODGE

Any further questions?

If not, thank you very much Jim.

That brings this session to a close unless Bill you have some final words with respect to standards?

BILL PORTER

Malcolm, I would just like to ask if you could say a few words about future plans.

MALCOLM LODGE

Our future plans are to hold a Technical Committee meeting tomorrow morning to listen to the presentations of the Sub-Committee Chairmen again with respect to their standards and to vote on some of them. The future is closing in on us, something like Cock Robin with the sky falling in. This Standards Development Programme has been funded through the NRC Energy Division and as such is in a somewhat tenuous situation. It's one of the areas that the new association will address to ensure that this initiative that has been commenced is ongoing so we can get to the end of the standards development procedure.

Our next activity of the Technical Committee will be to quickly put Sub-Committees in place to do the remainder of the work and to attempt to accelerate, as much as we can, the effort of the Sub-Committees to date. It must be remembered that this is all done very much on a voluntary basis with no compensation for the time or effort of the people involved. It's not always easy sometimes for those people in private life to attend the meetings and get to them. But we will do everything we can to see that these initiatives are not lost.

BILL PORTER

Thank you Malcolm for your well expressed summation.

Just in closing, I'd like to say that the Canadian Standards Association always appreciates the personal efforts of everyone who participates in these voluntary programs. The development of Standards is a very necessary function, and it is something from which Canadian manufacturers and engineers alike do derive mutual benefits.

If any of you who are not presently involved in these Sub-Committees, or the Technical Committee, but are interested in participating, we would appreciate hearing from you. We would like to get you involved. When we issue these in the next few months, either as preliminary Standards, or formal Standards, we will welcome your review, and your comments.

Once a Standard is published, it becomes a living document, and is subject to change. It must be continually updated on a periodic basis in order for it to remain of value to its users.

We'd like to thank you very much for staying this afternoon. This ends our panel discussion. Mr. Lodge has a few closing comments.

MALCOLM LODGE

Thank you, Bill.

That's the last of the scheduled programme. I'd just like to make a couple of announcements.

The new directors of the Canadian Wind Energy Association met this afternoon. I will report to you briefly what has transpired since the formation of the organization last evening.

We have elected a slate of officers. I am honoured to be elected as the President of the Association for the next year and look forward very much to trying to meet the challenge that's obviously there to us to try to continue the development of this industry. Our secretary is Vince Lacey and our treasurer will be Alex Printzios.

The first activity will be to prepare and present briefs to federal government agencies at the political level to ensure ongoing support for the industry. Priorities include: R & D, demonstration, standards work, and any area that we feel is an honest need to the industry and to the wind energy community.

The next meeting of the executive will be sometime in January when we hope to have our briefs and plans ready for that activity. We have even gone so far as to suggest that the next conference will be some time next fall in Ottawa, probably before the travelling gets too difficult.

TAPE CHANGED ..... section missing.....

Well, once again, I believe that we all owe Nicholas a very great vote of thanks and confidence in his endeavours to bring this meeting together. We look forward to many more Wind Energy Symposia over the forthcoming years. Please join me in offering a round of appreciation for Nicholas Teekman.

We are officially adjourned until October 1985.

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